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JANUARY 1986

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Front cover: Maryland Rail Commuter train heads for Washington, D.C. on Chessie Tracks past Washington metro Shady Grove station near Gaithersburg, Maryland.

Rear cover: Shady Grove station of Washington Metro (Washington Metropolitan Area Transit Authority) near Gaithersburg, Maryland.

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Comments on the Manual and Portfolio revisions shown on page 35 through 117 are welcomed from all readers and should be received at Headquarters by March 1, 1986.

Rail Transit

At its meeting December 5, 1985, the A.R.E.A. Board of Direction decided to establish a new Committee 12 - Rail Transit - to handle urban and suburban rail passenger matters.

With new rail rapid transit systems and extensions recently being opened or in the process of design and construction in several North American cities, as well as major reconstruction and rehabilitation projects under way on many rail transit systems, it was felt that there was a need for an A.R.E.A. group of people involved in this design, construction, and rehabilitation work, as well as those managing the day-to-day maintenance of rail transit systems. The work of setting up this committee is currently in progress, and you may be contacted regarding this if you are involved in commuter rail, heavy rail, or light rail transit. The chairman of the new committee is Dan Reagan of the Houston Metropolitan Transit Authority, 500 Jefferson Street, Houston, Texas 77208-1429.

For an appropriate cover story, photos were taken where the tracks of the Chessie System parallel those of the Washington D.C. Metro between Rockville and Gaithersburg, Maryland. The front and back covers and the photo above show the Shady Grove station of the Washington Metro to which service first began in December, 1984. The double-track Chessie line, in addition to heavy freight traffic, is host to Maryland Rail Commuter Service trains (as shown on the front cover) and Amtrak trains as shown above.

The photo below shows this new Washington Metro line under construction at Rockville.

Excerpts From 1985
Annual Report of A.R.E.A. Committee 1
Roadway and Ballast

H. C. Archdeacon, Chairman

Assignment 1. (a) Develop applications for use of undercutting taking into account existing subgrade conditions, depth and type of ballast, tonnage and possible maintenance cycle.

Substantial progress has been made on this assignment, but it is not anticipated that it will be finalized during 1985. Your committee feels that some clarification of the intent of the assignment is in order. It is recommended that the assignment be reworded to read: "Report on criteria including subgrade conditions; depth, type, size and condition of ballast; condition of track superstructure; tonnage and need for installing geotextiles, justifying the use of undercutters." It is anticipated that this assignment will result in an informational report in the Bulletin. A possible future subject for investigation would be the development of recommended practices in the use of undercutters.

Assignment 1. (b) Reinvestigate use of asphalt mixtures in railroad subgrades.

It is anticipated that this assignment will be completed this year with the submission of an informational report.

Assignment 1. (c) Gather information on new geo-related products (fiber reinforcement of soils, geogrids, etc.), reporting on possible railway applications.

There is presently circulating within the committee a letter ballot for the approval of a revised recommended practice for geotextiles in undertrack applications. If approved, your committee recommends that, when this is included in the Manual, it become part of a new Manual Section 10 of Chapter 1, titled "Geosynthetics." Your committee also anticipates the establishment of a new subcommittee to carry out future assignments in this rapidly developing field.

Assignment 1. (d) Review, update and rewrite stabilization text of the Manual including use of cement, lime and fabrics.

Some progress has been made on this assignment, but more emphasis will be needed. It is recommended that the assignment be reworded to more clearly define its scope. Your committee recommends that the assignment be reworded: "Update the Manual text on maintenance of roadbed."

As a new assignment for the roadbed subcommittee, your committee recommends the following: "Investigate and report on railway use of prefabricated concrete units for retaining embankments." Some of the committee members report that they are being confronted with proposals for using proprietary systems of this sort from highway departments, consultants, etc. It is felt that there is presently insufficient knowledge of their performance and potential problems in railway usage. The intent of this proposed assignment is to gather information on present and potential usage within the railway industry, any problems that may have been encountered and concerns of railway engineers. It is felt that such an investigation is a proper prerequisite to determining whether a recommended practice should be developed.

Assignment 2. (a) Develop plan of study for correlation of field performance with laboratory testing and progressing the studies until economic analysis can be made of various ballasts.

The plan of study is still under development. Some elements of the plan have not yet been identified. Others have been determined and study is in progress with a substantial amount of testing having been accomplished. It is felt to be appropriate at this point to split this into two assignments. The first, which would be the new assignment 2. (a), is to finalize development of the plan. The second which would be the new assignment 2. (b), is to continue to progress the parts of the study plan currently under way; as well as new elements once they are positively identified.

Assignments 2. (b) and (e) Furnish input to AAR ballast research program. Act as steering committee for AAR ballast research program.

Your committee feels that its relationship to the AAR ballast research program should be identified in a single statement, which would be the new assignment 2. (c). It should be noted that this is a continuing liaison function, and it is not expected to result in a report.

Assignment 2. (c) Review, analyze and report on results from AAR ballast research program and other appropriate research. Report how they fit with the long range plan.

It is anticipated that your committee will submit a report for the Bulletin this year commenting on AAR Report No. WP-110, Considerations of Factors Affecting Ballast Performance. Your committee recommends restating this assignment as the proposed new assignment 2. (d). This is also an ongoing assignment. It is separated from the new assignment 2. (c) because it includes sources other than AAR and will result in reports.

Assignments 2. (d) and (f) Draft modifications or revisions to A.R.E.A.'s recommended ballast specifications as indicated by results of tests and analysis.
Revise entire section for ballast in the Manual including ballast specification for concrete ties.

Your committee presently has a letter ballot circulating for approval of the major part of a new ballast specification. This document does not include everything that is ultimately anticipated to be recommended practice for ballast. However, it is sufficiently complete to replace the present ballast specification.

Goals for 1986 include the addition of a glossary and a subballast specification. It is also anticipated that as the long range study progresses, further modifications will be in order. These needs are addressed in the proposed new assignment 2. (e).

Assignment 3. (a) Study the use of geotextiles with rip-rap, gabions, pre-cast concrete units and other similar methods of erosion control.

Some work has progressed on this assignment, but it will not be finalized this year. It is recommended that this subject be reassigned to the new subcommittee on geosynthetics, and that it be restated to define the goal as the development of recommended practices. It appears in the proposed 1986 assignments as assignment 10. (a).

Two new assignments are proposed for the subcommittee on natural waterways. They are listed as assignments 3. (a) and 3. (b).

Assignment 4. (a) Sizing culverts for railway fills.

Your committee considers the present wording of the assignment to be vague, and recommends restating it as it appears in the proposed new assignment 4. (a). A considerable amount of work remains to be done on this assignment.

Assignment 4. (b) Develop use of plastic culvert pipe under railroad loading.

The committee's investigations have determined that presently available plastic pipe of sizes suitable for culverts are not suitable for railroad loading. It is proposed to terminate this subject with a brief report on the committee's findings.

Assignments 5. (a) and (b) Develop specification for use of casing pipe larger than 42 inches in diameter.
Study use of plastic carrier pipes.

I am not able to report progress on these assignments. It is recommended that they be continued. I am hopeful that we will see renewed effort to accomplish satisfactory progress.

Assignment 6. (a) Revise in decimal format.

Progress is being made on this assignment, but time will not permit finalization in 1985. Therefore, it is recommended that it be carried over to 1986.

Assignment 9. (a) Develop chemical use chart for the Manual.

A letter ballot is presently being circulated for the approval of a new chemical use chart. Upon approval this assignment will be completed.

Two new assignments are proposed for this subcommittee in 1986. One is to update the vegetation control glossary. The other is to develop recommended practices for roadbed spray patterns.

Proposed new Section 10, Chapter 1 of the Manual.

As previously stated, this section will begin with recommended practices for under track applications for geotextiles. This work has been accomplished, provided the letter ballot in circulation is approved. Two additional assignments are proposed for this subcommittee in 1986. They provide for the development of recommended practices for the use of geotextiles in erosion control and in drainage applications. These proposed assignments are shown as assignments 10 (a) and (b).

Excerpts From 1985 Annual Report of A.R.E.A. Committee 2 Track Measuring Systems

M.D. Roney, Chairman

Subcommittee 1 - Rail Planimetry — Chairman: A. Zarembski

Subcommittee 1 has been very active in defining parameters necessary to develop guidelines for automated measurement of rail profile. As a first step, a glossary of proposed definitions of rail surface defects has been prepared for submission to the AREA Manual.

The subcommittee is also coordinating a baseline study intended to gather field data from several railways on corrugation characteristics. The study will:

1. Define corrugations in terms of wavelength and amplitudes prevalent in North American freight railways.
2. Correlate growth with tonnage, traffic characteristics, and track characteristics.
3. Develop a relationship between corrugation growth and inspection and maintenance procedures.

Subcommittee 2 - Track Surveying — Chairman: G. Oberlechner

The track surveying committee is trying to establish the potential benefits of automated surveying of track. Such measurements would include clearances, track events (e.g. switch/crossing) location, track curvature, track gradient or track centers. The subcommittee is also concerned with how automated measurements would interface to existing company data bases.

The subcommittee has received data from member railways on what items of track survey information are currently stored in computerized data bases and how this information is derived.

Subcommittee 3 - New Technologies — Chairman: J. Choros

The objective of Subcommittee 3 is to evaluate the potential of new technologies to provide information about track that is not currently collected. Such measurements would include track modulus, subgrade moisture content and lateral tie strength.

As a first step the subcommittee has surveyed members on railway needs for new track measurements and is following up with a survey of what improvements railways would like to see in existing technologies such as track geometry measurement and rail flaw detection.

Subcommittee 4 - Track Geometry Car Development — Chairman: R. Harbuck

Subcommittee 4 has collected inventory data on the types of cars used by the various railways and has presented this in tabular format.

The subcommittee has also surveyed the track geometry defect definitions that each railway uses and the methods of measurement of each track geometry parameter. The survey showed large differences in the terminology used.

As a first step the subcommittee is proposing a standard set of definitions for crosslevel, surface, warp etc., for inclusion in the AREA Manual of Recommended Practice. Both the track geometry and rail planimetry subcommittees have chosen this direction initially as it is not possible to set standards for measurement systems without precise and standardized definitions of what is being measured.

Subcommittee 5 - Track Geometry Data Applications — Chairman: R. Doby

Subcommittee 5 is currently debating standardized methods of storing track geometry data and of reporting track quality.

Subcommittee 6 - Rail Flaw Detection — Chairman: R. McCown

The rail flaw detection committee was established at our May meeting following a decision by the AREA Board that such a subcommittee was needed to disseminate information to the industry on new detection techniques and capabilities of current techniques.

The initial task to be pursued by the committee is to evaluate the limitations on rail flaw detection with current technology. This information would be used both to evaluate the need for new technology and to provide input to Committee 4's work on establishing optimal rail flaw inspection intervals, which is closely tied to the capabilities and reliability of the measuring equipment.

Special Assignments

A. Light vs. Heavy Geometry Car Experiment.

Committee 2 is sponsoring, in conjunction with the FRA, an experiment to compare measurements taken by various geometry cars against actual track deflections measured under loaded 100 ton cars. The experiment will take place September 25 and 26 on Chessie track at Lyburn, West Virginia.

The objective is to evaluate how closely lightweight cars, attractive due to cost and flexibility, reflect the true loaded track profile and whether there are any appreciable differences in measurements taken under 2, 4 or 6 axle vehicles. For this purpose, a consist containing loaded and empty hopper cars, four and six axle locomotives, the Chessie TGC-2 Geometry Car, the FRA T-6 Geometry Car, the SS-1 Plasser Hi-Railer and Racine's Track Scan will run back and forth at various speeds through the site. The site consists of a jointed 4 degree curve with some pumping. Wayside instrumentation will record actual rail deflections under each car in the consist. These will be compared with measurements taken on board each car.

B. Crosslevel Index Validation.

Committee 2 is operating as a subcommittee of the AREA Adhoc Committee on Track Performance Standards, which is reviewing alternative FRA Track Safety standards. The task underway at present by the committee is the comparison of track exceptions identified by the TSC's proposed Crosslevel Index and Modified Crosslevel Index versus those found by existing railway definitions of crosslevel and warp exceptions. The comparison will cover 5,000 miles of Class 1, 2 and 3 track on six different railways. To date each participating railway has developed the software to calculate the new Crosslevel Indices and tabulations of comparative results is ongoing. If the new indices are found to be capable of locating existing FRA warp defects while providing important additional information on the sequences of crosslevel error that actually lead to rock and roll derailments, the FRA Office of Safety will be pressed to accept the Crosslevel Index as an alternate FRA Safety Standard.

A subobjective is to gain hands on familiarity with both indices and to develop a good understanding on the part of the industry of their ability to locate potential derailment sites.

Comments

We can only be very pleased in the enthusiastic response of the industry to this new committee, as shown in the large growth in membership. The Committee is still grasping with what is do-able and of value to the industry, and have already encountered problems with agreement on standard terminology.

At the same time some very good inventory data has been developed on track geometry measurement, the corrugation baseline study will provide excellent background for automated corrugation analysis, and the light vs. heavy geometry car experiment will answer some important questions related to the compatability of track measurements taken by different geometry cars.

The committee has experienced some problems with continuity of subcommittee assignments from one meeting to the next. The ability to get rapid and enthusiastic cooperation and to develop virtually any industry data required simply through internal surveys bode well for an effective contribution in defining opportunities and developing standards for automated track measurement.

Excerpts From 1985 Annual Report of A.R.E.A. Committee 3 Ties and Wood Preservation

J. B. Miller, Chairman

Subcommittee Reports:

Sub-Committee A - Recommendations for Further Study and Research:

This committee continues its search for new ideas and recommendations for further study in the areas of manufacture and use of wood cross ties. As always, we appreciate suggestions concerning study assignments.

We are continuing the monitoring of development of the following items:

1. Rail fastening systems for use with the wood cross tie.
2. Use of larger tie plates.
3. Use of wear control devices in tie plate area.
4. Use of split control devices.
5. The recycled or reconstituted tie.
6. The two piece steel dowel laminated wood tie.
7. The development and testing of a "Polymer" treated tie.

There has not been anything of any significance to report on the above items in the past year with the exception of item number 7. There has been very little activity in this field due to poor treatment quality of test ties on the Santa Fe. There is interest in continuing research and testing if quality test ties can be obtained. We have learned that a very reputable large company has shown interest in obtaining rights to the Al-Chem treatment. If they are successful it appears that there will be further development and testing. We will keep monitoring any activity in this field.

Sub-Committee B - Revision of Manual:

Presently the only proposed manual revision activity is in Part 5 and is being studied by an ad-hoc committee on switch tie specificiations.

Old Sub-Committee 1 - Metric Conversion has been abolished as authorized by the Board of Direction. Sub-Committees 2, 3, 4 and 5 have been renumbered 1, 2, 3 and 4.

Sub-Committee 1 - Cross Ties and Switch Ties:

Further revisions for Part 5 concerning switch ties are being studied at this time. Hopefully their recommendations will be ready for full committee votes early next year.

Sub-Committee 2 - Wood Preservatives and Preservative Treatment:

This Sub-Committee having recently completed a major manual revision with the combining of Parts 6, 7, 8 and 9 into a new Part 6 has no new developments to report. The Chairman is a member of AWPA Committee T-6 thereby keeping us updated on the latest activity concerning AWPA specifications.

Sub-Committee 3 - Service Records:

Under assignment (c), this sub-committee continues to work the research and product development committee of RTA in maintaining an up-to-date catalogue of all field tests of wood cross ties on the North American railroads. Assignment (a) report on the 1984 cross tie renewals is being compiled and will be forwarded to headquarters as soon as completed.

Sub-Committee 4 - Collaborate with the AAR and Other Organizations in Research:

We are becoming more active in collaborating with the AAR and other organizations, particularly universities, in research matters. As reported last year your Chairman serves as a member of a steering committee on a research project on wood cross ties at the University of Illinois. Since last year an additional research effort has been started by AAR and RTA jointly. Here again a steering committee was formed and I am also serving on this committee.

Last year I advised that Committee 3 was studying a research proposal by the Forest Products Lab of Mississippi State University. They proposed four projects:

1. Conditioning and treatment.
2. Method of inhibiting the iron degradation of Wood.
3. Methods of Stabilizing Wood Cross Tie Stock.
4. Bio-Assay of Ties.

All of these projects would be beneficial to the railroad industry. I highly recommend the proposals on Conditioning and Treatment and Iron Degradation of Wood. All of the proposals have been submitted to the AAR and RTA. Hopefully they will be able to fund some or all of the Mississippi State projects. In the past there has been very little research done in the wood cross tie field and we on Committee 3 feel that more must be done. Hopefully the Board of Direction will concur and carry our recommendations to the Engineer Division.

Proposed for 1986:

We will continue on all current assignments and will continue work on switch tie manual revisions. We will also continue to lend our support to appropriate research.

I am very concerned about the active contribution of the railroad engineering members of our committee. While the active participation of railroad members from Purchasing and other departments is very desirable and needed, I feel that more engineering skills are needed in making decisions regarding recommended manual revisions. In this regard, I will write all of our inactive railroad engineering members concerning their future on the committee. I would also like the Board's approval to write the Chief Engineers of the member roads soliciting new active railroad engineering members.

We propose to hold these meetings during 1986. The first during the Annual Technical Conference, the second as our annual field trip and the third in the fall in conjunction with the annual meeting of the RTA.

Excerpts From 1985 Annual Report of A.R.E.A. Committee 4 - Rail

R.E. Catlett, Jr., Chairman

Subcommittee Reports:

Subcommittee A - Recommendations for Further Study and Research

All recommended subjects for study have been assigned to the appropriate subcommittee.

Subcommittee B - Revision of Manual

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

Subcommittee 1 - Collaborate with AISI Technical Subcommittee, Welding Contractors, Suppliers of Field Welding, Rail Grinding and Rail Testing Contractors on Matters of Mutual Interest

The Ad Hoc Committee on Rail Profiling held a meeting on March 27 and reviewed results from two field tests involving fifteen curves with six months service on the CN and CP. The goals of both tests are to determine the effects of asymmetric grinding of the running surface of the rail and gauge face wear on curves. Profile grinding tests are also being conducted on the ATSF, BN, FAST, and NS comparing contoured curves with standard profile curves. A progress report is expected at the October meeting of the Committee.

Physical testing has begun on the 132# welds for the Weld Qualification Testing Committee. It is intended that 38 welds, both 132# and 115#, of various combinations of metallurgies be made using four different welding machines.

The Ad Hoc Committee for Magnetic Particle Inspection has completed their assignment. "Magnetic Particle Inspection Procedure Guidelines" have been approved for inclusion in the manual.

An Ad Hoc Committee is studying High Strength Rail Welding. At present they are awaiting parameters for welding high strength rails which are being developed by the Weld Qualification Testing Committee.

Subcommittee 2 - Collaborate with AISI Technical Committee on Rail and Joint Bars in Research and Other Matters of Mutual Interest

The AISI Technical Committee is furnishing the Rail Committee survey results on rail symmetry, rail height, base width, and flange thickness of rail producting mills. They are also working with Subcommittee 5 on revisions to the rail specification on ultrasonic testing, stamping, sidesweep, long rail lengths and tolerances, waviness, twist, macroetch standards, symmetry, flange thickness, and base flatness.

Subcommittee 3 - Rail Statistics

(a) Report on the Premature Rail and Weld Failures.

The last report on rail statistics was published in Volume 82, Bulletin 681, which included statistical data through 1979. The new subcommittee chairman is in the process of reviewing and assembling in report form information furnished by most railroads for years 1980-1982. The report has been badly delayed by the lack of support by several major railroads without whose information the report would be worthless. Unless more cooperation is received from major railroads, the Committee will recommend the subject be discontinued. Statistical information for the years 1983-1984 will be requested from the Chief Engineers in the near future. Their respondences will influence our decision.

Chief Engineers are also being asked to furnish information on premature rail failures. A premature or "early" rail failure is defined as "a nonweld oriented failure that would occur within 100 MGT or within three years of service including a detector car test in the third year."

Subcommittee 4 - Update Data on Methods and Equipment for Making Welding Repairs to Rail and Turnouts

The subcommittee more than a year ago circulated a questionnaire requesting procedures and experiences in making repairs to the running surface of alloy rails of different types. At that time, the railroads indicated very limited experience with alloy rails.

The questionnaire will be updated and recirculated.

Subcommittee 5 - Rail Specifications, Research and Development.

(a) Develop a Specification for Rails Longer than 39 feet including a Definition for "Long Rail."

Revised rail specifications have been circulated for ballot approval. The main revisions provide for changing the minimum brinell for standard rail from 269 to 285, branding not to occur within two feet of either end of rails of standard length, ultrasonic testing to become a part of the specification rather than being a supplemental requirement, and tolerances for uniform lateral sidesweep and twist. As soon as an Ad Hoc Committee develops a set of macroetch standards, it will be recommended that the drop test requirement be eliminated.

The committee approved by letter ballot a change to the "Recommended Field Repairs to Pressure Butt Weld Failures," Pages 4-2-6.10 and 4-2-6.11 of the manual.

The following subjects are being studied:

1. Revision of "Inspection and Classification of Secondhand Rail for Welding," Pages 4-2-6.5 and 4-2-6.6 of the manual.
2. New photographs for Pages 4-M-3 and 4-M-4.
3. Review and update test reports and include as a part of the specification.
4. Specification for base flatness.
5. Include a statement indicating the acceptable martensite level.
6. Specification for tools for measuring rail tolerances.
7. Develop macroetch standards for continuous cast rails.

The revisions to the rail specification now being circulated for ballot approval should complete the assignment to "develop a specification for rails longer than 39 feet including a definition for long rail."

Subcommittee 6 - Joint Bars: Design, Specifications, Service Tests, including Insulated Joints and Compromise Joints

(a) Develop Specifications for Fabrication of Bonded Insulated Rail Joints

The subcommittee completed the assignment to revise "Specifications for Quenched Carbon-Steel Joint Bars and Forged Compromise Joint Bars," page 4-2-12 of the manual. The revision has received ballot approval and has been submitted for manual revision.

The above-mentioned new assignment is being studied.

Subcommittee 7 - Effects of Heavy Wheel Loads on Rail

A preliminary report on rail wear of BN's curve #30 was presented to the Committee on May 16. Analysis of the BN Gillette Line wear data is virtually complete and will be submitted to the Committee at its October, 1985 meeting.

The subcommittee met in Montreal on March 14-15. New information on lubrication from the Transportation Test Center, the Western Laboratories of the Canadian NRC, and the CN and CP railroads was presented. To further the dissemination of new information on wheel/rail lubrication, a workshop has been planned for November 11-12, 1985. Representatives from the railroad industry, from academia, and the manufacturers of lubricants and lubricator systems will present technical information about railroad experience and product characteristics. This workshop is being arranged in conjunction with Subcommittee 7 of AREA 5.

The new question assigned to the subcommittee concerning proper head profile to be achieved by grinding has been examined by curving force analysis and by finite element as well as photo elastic contact stress distribution analyses. The curving analyses have shown that the change in wheel/rail forces and wear indices is very sensitive to actual wheel/rail profile used in the analysis. Grinding can cause the forces and indices to increase or decrease depending upon specific profile configuration. The 20 finite element and photo elastic analyses done suggest that the separation of the vertical and lateral wheel loads which can be achieved by gauge corner grinding results in less effect upon the contact stress distribution than had been anticipated. Currently a more realistic 3D analysis is being developed.

Subcommittee 8 - Field Welding

This subcommittee is continuing their study to determine the methods and advisabililty of performing non-destructive testing of field welds immediately following installation.

Subcommittee 9 - Recommendations for Interval of Non-destructive Testing for Internal Defects of Rail in Track

(a) Provide Review and Evaluation of FAST Rail Experiments on Rail Inspection Sensitivity Assessment.

The subcommittee completed the assignment to develop recommendations for "Determining Minimum Detector Car Test Intervals." Ballot approval has been obtained and the recommendation submitted for publication in the manual.

The subcommittee is proceeding on a new assignment.

The Committee has previously indicated an interest in rail research concerning the following five topics:

(1) Weld structural strength tests
(2) Macroetch standards
(3) Steel cleanliness effects
(4) Rail grinding
(5) Track modulus effects

Weld structural strength testing, steel cleanliness effects, and rail grinding are covered in the AAR 5 - Year Research Plan. The topic of macroetch standards is being addressed by the rail manufacturers that have continuous casting equipment. The Committee has an Ad Hoc group that includes manufacturing representatives that is working to develop a set of macroetch standards for inclusion in the rail specification. The topic track modulus effects is within the scope of the planned research, but the status is not known.

I hope we can get members of Committee 4 involved in one or more working groups which will provide commentary and critique to the experiments involving rail performance.

Excerpts From 1985 Annual Report of A.R.E.A. Committee 5 - Track

N. H. Clark, Chairman

Your committee reports on the following subjects:

A. *Recommendations for further study and research*

B. *Revision of the Manual - Chairman R. W. Blank*

(a) Review anchor pattern for bolted rail and CWR. This assignment is a joint venture with Subcommittee 7. The revised section was submitted to full Committee vote, and passed. It will be printed soon.

(b) Review current anchor application and maintenance procedures in collaboration with Subcommittee 7, Track Maintenance.

The subcommittee is preparing a questionnaire to canvas the various railroads regarding the use of second-hand anchors.

(c) Review rail laying temperatures for CWR in collaboration with Subcommittee 7, Track Maintenance. See Subcommittee 7 for coverage of this assignment.

2. *Track Tools - Chairman R. L. Teeter*

(a) Review inclusion of new and additional track tools. Assignment (a) is a continuing subject and during the forthcoming year this subcommittee plans to redraw certain tool drawings for better clarity, continue their investigation of impact resistance handles and study tool eyes as currently shown on various AREA tool plans.

(b) Develop specifications for abrasive wheels and their recommended use in track, collaborating with Subcommittee 7, Track Maintenance. A recommended practice covering the use of abrasive wheels was put out to full committee vote. If passed, it will go for publication. Assignment to be continued.

4. *Track Design - Chairman L. E. Daniels*

(a) Evaluate elastic fastener system designs for wood ties and establish minimum recommended performance standards.

Mr. Daniels compiled a large amount of information from the Fast experiments, which was distributed to the members for their perusal. The committee should soon have some recommended practices available.

(b) Hold-down fastenings - wood ties - evaluate standard AREA cut spikes, vs. lock spikes, drive spikes and screw spikes as to their effects on reducing plate cutting of the ties and gage widening. Here too, Fast results are being reviewed, and recommendations should be forthcoming.

(c) Tie plates - wood ties. Review existing tie plate plans (i) for accuracy and update as required including provisions for cant of plate and other pertinent design and usage criteria.

(ii) Reassess spike hole size for plate holding purposes.

Both of the above assignments were reviewed and recommendations will be made soon.

Assignments to be continued.

5. *Turnout and Crossing Design - Chairman R. J. Banchero*

(a) *Review of Guardrails Protecting Turnout Frogs.* The Committee is continuing its investigation into guardrails protecting turnout frogs. They have now decided to look at the use of longer guardrails with single cut flares instead of double cut. Guard rail lengths being considered are 14'-0", 18'-0" and 24'-0". Assignment to be continued.

(b) *Investigate the worn-wheel ramp on rail bound frogs.* This was discussed and the subcommittee reached a consensus. A letter ballot has been sent out to all Committee members for their approval.

(c) *Investigate use of gage plates on turnouts to maintain gage.* This subject was reviewed, and the committee noted that at present five railroads use such plates. Plans of those plates in use will be reviewed. Assignment to be continued.

(d) *Develop specifications for explosion hardening of trackwork castings.* It was suggested that the explosive hardening be dropped from this assignment, and that the manufacturer would be allowed to harden the frog to the minimum Brinell by whatever means he wished. A ballot has been circulated to this effect. Assignment to be continued.

(f) *Develop recommended maintenance parameters for frogs, switches, guardrails and crossings.* Information still being gathered. Assignment to be continued.

6. *Track Construction - Chairman E.C. Rudolph*

The committee reviewed the existing CWR Track construction method and plan to update it in light of new methods available.

7. *Track Maintenance - Chairman A. Zierow*

(a) Study rail lubrication, collaborating as necessary with Committee 4.

The committee is reviewing information presently on hand. They also plan to prepare a questionnaire for all railroads covering not only curve lubrication but also full track lubrication.

(b) Review rail laying temperature for CWR in collaboration with Subcommittee B. Ballots covering this assignment have been sent to the full membership. Assignment to be continued.

8. *Criteria for Track Geometry Design - Chairman M. E. Wilson*

(a) Study ballast shoulder width as it relates to holding track geometry, collaborating as necessary or desirable with Committee 1 and Subcommittee 6.

A questionnaire to all railroads has been prepared covering the existing ballast section widths. Replies will be reviewed and recommendations made. Assignment to be continued.

(b) Study the underbalance of superelevation and the effects on track.

A questionnaire has been made up for this assignment also. Assignment to be continued.

(c) Study the effects of lock of superelevation in high speed crossovers.

Computer runs of previous calculations will be made to see if a method can be devised to increase speeds.

Excerpts From 1985 Annual Report of A.R.E.A. Committee 6 - Buildings

R. E. Phillips, Chairman

III. Manual Revisions and Recommendations

In an effort to keep Chapter 6 of the manual current the entire chapter is being reviewed. The status of each part is as follows:

Part 1 - Specifications—1983, current. No action needed.

Part 2 - Railway Offices - 1975, being reviewed by Sub-Committee 3, see status under Section IV of this report.

Part 3 - Car Shops - 1973, being reviewed by Sub-Committee 2, see status under Section IV of this report.

Part 4 - Diesel Shops - 1975, being reviewed by Sub-Committee 4, see status under Section IV of this report.

Part 5 - TOFC - COFC Facilities - 1973, this section is outdated and falls under the purview of Committee 14 - Yards and Terminals. Any support buildings necessary in a TOFC facility can be designed from Part 2, Railway Office Building Criteria. This part has received approval by the Board to be deleted from the manual.

Part 6 - Sanding Facilities - 1975, Section being reviewed by J.H. Smith to determine if major revision is necessary. If so a new Sub-Committee will be formed.

Part 7 - Pre-Engineered Metal Buildings - 1975, this section describes material and products that are not Rail Industry specific and are more adequately detailed in other technical references. As such, the routine updating of this section is not required and has received approval by the Board to be deleted from the manual.

Part 8 - Rail Passenger Stations - 1985, Current. No action needed.

Part 9 - Central M of W Shops - 1976, Section being reviewed by J.G. Robertson to determine if major revision is necessary. If so a new sub-committee will be formed.

Part 10 - Yardmasters Towers - 1976, section has been reviewed by D.A. Bessey - Only minor revisions are necessary and this will be handled at the next regular committee meeting.

Part 11 - Portable Buildings - 1978, section describes products and criteria that are more adequately presented in non-rail industry sources. This part has received approval by the Board to be deleted from the manual.

Part 12 - Loco Washing Facilities - 1979, section is being reviewed by J.H. Smith to determine if major revisions are necessary. If so a new sub-committee will be formed.

Part 13 - Freight Forwarding - 1981, current. No action needed.

Part 14 - Roofing - 1981, current. No action needed.

Part 15 - Inspection of Buildings - 1984, current. No action needed.

Part 16 - Halon Fire Suppression - 1985, current. No action needed.

Part 17 - Bibliography of Reports - 1986. In 1983 a bibliography of past Committee 6 reports was printed as information (Bulletin 693, page 412). This listing provides a valuable reference to retrieve information that is not incorporated into the manual. This new section has received approval by the Board and should be a part of the 1986 manual material issue.

IV. Current Status of Subcommittee Assignments

Subcommittee A - Recommendations for Further Study and Research
Chairman J.G. Robertson

Updating the manual sections has been put ahead of further study for the moment. However, suggested topics for future consideration are plant maintenance procedures, maintenance, construction costs, asbestos removal, CADD system operation, and facilities management.

Subcommittee B - Revision of Manual
Chairman R. E. Smith

This subcommittee has been active in arranging various final reports in correct format for publication and in coordinating our effort to update all manual sections.

Subcommittee 1 - Design Criteria for Centralized Dispatching Facilities
Chairman E. L. Barratt

This subcommittee has had some problems with switching chairmen over the past year and little has been done. It now appears that we have an active chairman and a draft report is expected for review at our next committee meeting.

Subcommittee 2 - Design Criteria for Car Shops
Chairman W. C. Sturm

The plans are to revise the existing manual chapter on one spot car repair shops and add material on other types of car shops. The intent of the Committee was to completely write this report at our May meeting which was to be a design workshop on Car Shops. As this meeting was cancelled this was not done. An outline draft is expected at our next Committee meeting.

Subcommittee 3 - Design Criteria for Railway Office Buildings
Chairman W. Ehmann

Mr. Ehmann has not been present at the last three Committee meetings and has not progressed a recommendation on updating this section of the manual. W.C. Sturm will contact Mr. Ehmann to ascertain what action or problems are being encounttered and if necessary a new chairman will be assigned at our next meeting.

Subcommittee 4 - Design Criteria for Diesel Locomotive Facilities
Chairman S. D. Arndt

A working session of reviewing the existing manual material and formulating an outline of which sections need updating, deletion or amplification was completed. This section will be ready for further discussion at our next meeting and tentatively scheduled for a vote in mid 1986.

Subcommittee 5 - Architectural Design Competition
Co-Chairmen: D. A. Bessey & W. C. Sturm

Judging of the entries was done on February 4, 1985. The winner was Miss Jamie Lis from the University of Illinois. Miss Lis presented her entry and received the first place award of $1,000 at the annual technical conference in March. Second place went to Paul Wheeler also from the University of Illinois. Five Honorary Mention Awards were given as follows: R. E. Castillo, University de Monterey, Monterey, N.L. Mexico; Kean C. Fong, Texas Tech University; Thomas Loew, University of Illinois; Aida Mohamed, Texas Tech University; and Gary J. Nelson, Hampton University.

The architectural competition was considered successful, although with the limited number of entries received it was not as successful as the past two competitions sponsored by Committee 6. The limited number of entries was largely due to increased competition from other more lucrative design competitions. It was suggested that in the future, we consider working with one or two schools that historically have participated in Railway problems. One suggestion was a comprehensive design of a yard involving many buildings and civil engineering works that would teach students the elements of multi discipline teamwork as would be found in a Railway Design office or a large private practice. This approach would have to be jointly administered with several other committees. This concept will be explored further by the Co-Chairmen.

Subcommittee 6 - Energy Conservation and Audits
Chairman, J. H. Smith

At our January meeting Mr. Smith distributed a comprehensive draft report for discussion and mark up. The report contains very detailed audit formats and checklists which will be very helpful to management employees who are charged with energy management of facilities. It was the consensus that the detailed lists and audit formats should be made attachments to the report. The report will outline the elements of an energy program, identify the strategies for justifying a program, and identify how to do different types of audits and use the data collected as a management tool to reduce operating costs. A vote by the Committee is tentatively scheduled for our next Committee meeting.

Excerpts From 1985 Annual Report of A.R.E.A. Committee 7 - Timber Structures

R. W. Thompson, Jr., Chairman

Subcommittee A - Recommendations for further study and research

In 1982, Mr. Gustafson, with the help of the entire committee, put together the recommendations that were sent to F.A.S.T. These recommendations were very extensive; and if put into operation, would clear up a lot of unknown forces. We would like to have these recommendations tested at F.A.S.T.

Subcommittee B - Revision of the Manual

Mr. Markvaldas has completed the Reorganization and Decimalization of Chapter 7. This has been sent to the members of Subcommittee B for their comments and editing. It is expected that any corrections required will have been completed and the material sent to the entire Committee 7 by February 1986. A target date of August 1, 1986 has been set for submitting the reorganized manual to A.R.E.A. headquarters for printing and distribution.

Subcommittee 2 - Grading rules and classification of lumber for railway uses; specifications for structural timber collaborating with other organizations interested.

Revised specifications on timber piles have been submitted to the Subcommittee. Full response has not been received to date.

Subcommittee 3 - Specifications for design of wood bridges and trestle.

Since assuming the duties of Chairman of Subcommittee 3 in September of 1984, Mr. Uppal has been very active and submitted a questionnaire to all Chief Engineers which is quite extensive. The results are just now coming in; and when they are compiled, we will publish the results in the bulletin and send a copy to each responding road.

Subcommittee 5 - Design of structural glued laminated wood bridges and trestle.

This committee has completely revised the glue laminated section of the manual. The revised section has been published in the bulletin. This committee will also be ongoing and will monitor various other organizations and the AITC.

Subcommittee 6 - Effect of unit trains on timber trestle components.

Mr. Brookings has sent a questionnaire to each subcommittee member to determine what problems, if any, each has experienced that could be attributed to the action of unit trains on timber trestles and their components. Due to increased responsibilities, Mr. Brookings has not been able to summarize the results to date.

Subcommittee 7 - Effect of dapping and end overhang in bridge ties.

Mr. Gunkle has been very active on this subcommittee since assuming the chairmanship and has submitted a questionnaire and supplemental questionnaire to the Chief Engineers of all Class I Railroads. The response was very good; consequently, Mr. Gunkle is presently tabulating the results. Once the results have been acted upon by the committee, each Railroad that responded will be sent a tabulation of the results. The results will also be published in the bulletin.

Subcommittee 8 - Protection of pile cut offs, protection of piling against marine organisms by means other than preservatives.

Mr. King is in the process of writing a closeout report.

Subcommittee 9 - Study of in-place preservative treatment of timber trestles.

All materials have been tabulated and discussed at committee meeting. The final report will be sent to full committee for vote as soon as the so called "Threshold Limit" of penta can be documented.

Excerpts From 1985 Annual Report of A.R.E.A. Committee 8 - Concrete Structures and Foundations

H.R. Sandberg, Chairman

Committee 8 reports on the following subjects:

A. Recommendations for Further Study and Research

The full committee unanimously and strongly recommends that, when research funds become available, the request made by the committee several years ago for funding of a project to determine impact stresses in concrete bridges be given consideration. Computer models have been developed to analyze these stresses, but field data is needed to verify and "benchmark" the models. Impact has a number of causes such as speed of loading, degree of vertical curvature, type of track support, type of track and condition of rolling stock such as flat spots on wheels. Load factor design would permit the assignment of different factors to normal and to unusual causes resulting in a more realistic design or rating.

B. Revision of Manual

Subcommittee 1 - Design of Concrete Structures

Subcommittee is in the process of revising Part 19, Rules for Rating Existing Concrete Bridges. The AASHTO rating criteria utilize the load factor design method, and studies show that for highway bridges with low live load to dead load ratios this is satisfactory. For railroad bridges with high live load to dead load ratios the load factor design criteria for shear give a substantially lower rating than the working stress design criteria. This illogical difference is being studied in depth.

New Part 13, Precast Concrete Box Culverts, and an addition to Part 17, covering design of precast and cast-in-place segmental concrete bridges, were submitted to the full committee for letter ballot, but major comments arose that are being resolved.

The criteria for design of bridges in zones of seismic danger developed by AASHTO are being studied in cooperation with Committee 15. A meeting of either the full committee or a special subcommittee with the Applied Technology Council (the group which developed the AASHTO specifications) is being planned.

The criterion for pier protection walls which now requires 2'-6" thick crash walls for piers located within 25 feet of a track is being studied. This criterion was questioned by Committee 28, and subsequent investigation revealed a need for specifications covering not only piers but other sensitive structures.

Subcommittee 2 - Foundations and Earth Pressures

Parts 3, 4 and 5 are being reviewed by the subcommittee for updating and revision.

The subcommittee is preparing a full revision to Part 6, Crib Walls, to include all types of materials.

The subcommittee continues to cooperate with and review the work of the other subcommittees as it relates to foundations and earth pressures.

Part 18, Elastomeric Bearing Pads, had been withdrawn from the manual by the committee. Tests conducted by the University of Washington on bearing pads for AASHTO are now complete. Results from these will be released soon and will be incorporated in new specifications coordinating with Committee 15.

Subcommittee 3 - Waterproofing and Other Protective Systems for Railway Structures

Subcommittee continues to monitor products, procedures and related activities as they relate to the protection of concrete structures.No new chapter revisions are planned.

Subcommittee 4 - Strengthening Existing Concrete or Masonry Structures and Restoration of Existing Structures to Restore Original Structural Capacity and Durability

Revisions to Part 23, Pier Protection Systems at Spans over Navigable Streams, have been approved by the full committee and will be published as manual material in 1986.

The subcommittee is currently preparing a section on the use of slurry walls, both as a structural element and as a cutoff wall.

A new structural element making the use of arches competitive and practical, both for new construction and rehabilitation, is being studied and may require the development of a new part.

Excerpts From 1985 Annual Report of A.R.E.A. Committee 9 - Highway-Railway Programs

A. D. Moore, Chairman

Committee 9 has continued to pursue all 11 subjects assigned for investigation and reporting. There was no assignment of new subjects and we are recommending at this time that two subjects be deleted. No additions are contemplated at this time, however, we are reviewing the entire Committee 9 assignment and goals which should be completed shortly. The following is a brief summary of subcommittee activities for the past year and anticipated activities for the next year.

Subcommittee A - Recommendations for Future Study and Research: Cliff Shoemaker, Chairman.

This committee continues to monitor the activities of the other subcommittees to ensure their titles are appropriate; that new subcommittees are recommended as necessary; and that existing subcommittees are dropped when the assignments are completed. It has taken on the task of handling the reorganization and reassignment of Committee 9 and also helping to set up goals for each subcommittee, subcommittee chairman, member, vice chairman, secretary and chairman of this committee. This is to be forwarded to all members, shortly.

It also continued in evaluating new developments in the areas relating to the committee as a whole, especially in the area of research, to ensure that the committee is kept abreast of new developments. It also maintains a liaison with other committees such as TRB as well as other research granted organizations such as TSC. This is a continuing assignment and is intended that this subcommittee be continued.

Subcommittee B - Revision of Manual: Kurt Anderson, Chairman

Further revision of Chapter 9 is progressing at this time. It is hoped that the subcommittee will have a manual revision yet this year. Subcommittee B will continue to coordinate with other subcommittees for manual revisions. This is a continuing topic and is intended that this subcommittee be continued for future manual changes as required.

Subcommittee 1 - Drainage and Foundations for Highway-Railway Grade Crossings: Bob Brozio, Chairman

This subcommittee changed chairman this year. Mr. Nichelson had to resign due to other duties and Mr. Brozio, who was vice chairman was elevated to the position of chairman. The subcommittee also was given a new assignment and is now working towards completing that assignment. It is recommended this assignment be continued for another year until this work can be completed.

Subcommittee 2 - Types of Grade Crossing Surfaces: Roger Skinner, Chairman

This subcommittee gathers and disseminates information on the various types of grade crossing surfaces. It has reviewed several state reports concerning the various grade crossings material types that are now in the highway system. The committee continues to feel that testing by AAR laboratory or an outside laboratory is desirable to give some independent means for selection of surfaces to meet specific crossing conditions. This subcommittee will continue to coordinate with Subcommittee B on manual changes and additions and will explore further appropriate means for testing and comparing crossing surfaces. It is recommended that this assignment be continued.

Subcommittee 3 - Summary Reporting of Significant Publications on Grade Crossings: Harold Michaels, Chairman

This subcommittee continues to review and report on various publications involving highway-railway intersections that it determines will be of interest to the AREA members. Liaison is maintained with research organizations as well as other related committees to share information and to obtain access to additional sources of material. This is a continuing subject with addendums being prepared frequently and revised reports prepared every two to three years. It is recommended that this assignment be continued.

Subcommittee 4 - Evaluation of Developments in Passive and Non-Train Activated Grade Crossing Traffic Control Devices: Don Taylor, Chairman

This committee continues to monitor developments in the area of passive warning devices. Some of the changes recommended by this subcommittee have been incorporated in other manuals. It was reported this year concerning the new standard crossbuck sign to be used in Canada. This is a marked difference between the standard now used by United States Railroads and the Canadian Railroads. It has also been recommended that the assignment of Subcommittee 6 - Traffic Control and Railway-Highway Work Zones, now be monitored up by this subcommittee. It is felt that continued monitoring of this assignment should be continued. It is recommended that this subcommittee be continued.

Subcommittee 5 - Grade Crossing Safety and Public Awareness: Dick Mather, Chairman

This subcommittee has continued to cooperate with the National Safety Council for the implementation of sample questions for driver examinations. The subcommittee maintains liaison with the National Safety Council through their National Director of the Operation Lifesaver Program, who is a member of this subcommittee. A committee member is also a member of the AAR Operation Lifesaver Substeering Committee. It has been recommended that Subcommittee 8 - Railway-Highway Public Interaction be reassigned to this committee as it is apparent that with the resignation of the Subcommittee 8 chairman, there is not enough interest to keep Subcommittee 8 alive. It was decided that Committee 5 should pick up these assignments and continue them. It is recommended that this subcommittee be continued.

Subcommittee 6 - Traffic Control and Railway-Highway Work Zones: Bobby Joe DeRamus, Chairman

With the publication in Bulletin 701 dated May, 1985, this subcommittee assignment was completed. All future monitoring of this particular item will be handled by Subcommittee 4. It is recommended at this time to the Board of Directors that this subcommittee assignment be abolished This subcommittee should be discontinued.

Subcommittee 7 - Evaluation of Developments in Train-Activated Grade Crossing Traffic Control Devices: Jay Ragsdale, Chairman

This subcommittee continues to maintain a liaison with AAR Committee D and report on their activities. The subcommittee is continuing to monitor any activated warning devices that have been proposed for development. It is recommended that this assignment be continued.

Subcommittee 8 - Railway-Highway Public Interaction: Bob Downey, Chairman

Mr. Downey has resigned as subcommittee chairman and in discussion with the committee, it was felt that there was no need for this particular assignment to be carried as a separate subject. It was recommended that this assignment be incorporated in Subcommittee 5's activities. It is recommended at this time that the Board of Directors approve the combination of Subcommittee 8 into Subcommittee 5's assignments. The subcommittee should be discontinued.

Subcommittee 10 - Summary Reporting of Administration of State Crossing Safety Programs: Paul Oakley, Chairman

This subcommittee has kept the committee's members as a whole, aware of the status of the grade crossing program in general. Included in this area were reports as to the current legislation providing funding for crossing improvements, the status of rule making procedures, the situations regarding obligation rates of funding currently available, current developments being handled by AAR that effect crossing programs on the national level. Additionally this subcommittee reported on local, regional and national meetings involving the grade crossing programs that were of interest to the committee. It is recommended that this subcommittee assignment continue.

Excerpts From 1985 Annual Report of A.R.E.A. Committee 10 - Concrete Ties

R. J. Brueske, Chairman

Listed below are the sub-committees along with a report of their activities the past year:

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

This Subcommittee is recommending a research project to: "Establish the effect of crack causing loads on tie life".

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

This Subcommittee is reviewing our Manual material to determine what changes or additions may be required to include Post Tensioned Concrete Ties. There are a large number of post tensioned concrete ties in service throughout the world and the Committee believes they should be covered in the Manual.

Subcommittee - Assignment 1 - "Flexural Strength"

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

(b) Review of Table II in Section 1.5.1, Two Block Ties

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

This Sub-Committee has rewritten some of the definitions on page 10-1-3, added a Section 1.2.3.12(a), rewritten Section 1.2.3.13 on page 10-1-12, rewritten Table II for Two Block Ties on page 10-1-18 and rewritten Sections 1.9.1.2(b), 1.9.1.5, 1.9.1.8, 1.9.1.10, 1.10.1.2(c), 1.10.1.6, 1.10.1.7, 1.10.1.11, 1.13.2.1, and the sketches on pages 10-1-44 and 10-1-45. This completes the work on Assignment (b).

Work on Assignments (a) and (c) continues and a progress report will be submitted at our September 18th meeting.

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

This is a new assignment and the Subcommittee will hold it's first meeting September 18th. They have a tentative list of items to cover. We are fortunate that test installations are already in service to aid us in our work.

Subcommittee - Assignment 3 - "Fastenings"

(a) Revise current test requirements

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

The Subcommittee is currently concentrating their efforts on the revision of the current test requirements. We had hoped to be in a position to put the revision out for a ballot in 1985. We have been slow in arriving at a compromise that will be able to secure committee approval. Perhaps we will have a recommendation by the fall of 1986.

Subcommittee - Assignment 4 - "Test Requirements"

(a) Investigate tie pad and insulator requirements

The Subcommittee has completed this assignment and ballot approval of the manual changes has been received. The revisions will be in the next year's manual revisions.

The Subcommittee is recommending two new assignments for Board approval. The proposed new assignments are:

1. "Review and recommend revisions of the load magnitudes specified for the Fastening Repeated-Load Test".
2. "Review and rcommend revisions of the Rail Seat Overload and Ultimate Load Test for Two Block Ties".

Subcommittee - Assignment 5 - "Investigate Ballast Requirements"

The Subcommittee has made an extensive study of this assignment and our efforts were partially a duplication of Committee 1's work to rewrite the ballast section of the Manual. We will review the recommendations we were proposing and compare them with Committee 1's proposals. If we find any significant disagreement, we will give Committee 1 our suggestions. It appears that this assignment should be dropped for 1986.

Nearly six years has passed since the committee was formed from the special Ad Hoc committee. During that period, we have learned a great deal and this knowledge has resulted in the many changes to our Manual material. Further changes can be expected as the various concrete tie installations accumulate additional years of service.

This is my last year as Chairman of Committee 10 and I have been very fortunate in having many dedicated and extremely knowledgeable members on the Committee that have made my job a real pleasure.

Excerpts From 1985 Annual Report of A.R.E.A. Committee 11 - Engineering Records and Property Accounting

J. W. Kelly, Chairman

Report of Activities for the Year 1985

Progress of Subcommittee Assignments:

Subcommittee "A" - Recommendations for further study and research. No new recommendations.

Subcommittee "B" - Revision of the Manual. Review ongoing, but progress has been curtailed due to personnel changes.

Subcommittee 1 - Accounting

The implementation of the Interstate Commerce Commission order adopting track depreciation has occurred. The order permits individual railroads flexibility in compliance, which has resulted in several variations of methodologies. Your committee made a presentation of these applications to the 1985 Technical Conference. A report for the Bulletin and a Manual update will be forthcoming after some experience has occurred.

Subcommittee 2 - Office and Drafting practices

The study of possible development of a property record which would satisfy both engineering and property accounting requirements is continuing. The ICC adaptation of track depreciation has substantially altered the approach that should be taken and will necessitate a partial "new beginning" of this study.

Subcommittee 3 - Taxes

The principal objective of this Subcommittee is to collect and disseminate information about taxes of all sources and types which affect property management, investment and recordkeeping responsibilities.

Excerpts From 1985 Annual Report of A.R.E.A. Committee 13 - Environmental Engineering

R. J. Spence, Chairman

A. Sub-Committee Subjects

Prior to discussing the various sub-committee assignments a re-affirmation of the numbering order of assignments is necessary. Parts 1 through 3 of Chapter 13 will remain unaltered insofar as basic subject material is concerned. However, Part 4 of the manual material has been deleted in 1985. Certain sections of this part, dealing with Industrial Hygiene will be incorporated in Part 5, Plant Utilities which is being extensively revised. A new Part 4 entitled Noise Pollution Control is planned to be incorporated into Chapter 13. Corrosion Control, Part 6 will be eliminated and incorporated into Chapter 5.

1. Water Pollution Control

Assignment for 1985 "Leaking Underground Storage Tanks (LUST)" - Summary of proposed regulations and remedial techniques was hampered by a late promulgation of E.P.A. regulations. Work on this subject is proceeding and will be further refined in 1986.

2. Air Pollution Control

Assignment for 1984 "Investigate Techniques for Removal and Disposal of Asbestos from Railroad Facilities" has been submitted for information in the *Bulletin*. Work is progressing on the 1985 assignment which entails an extensive revision of the existing manual material.

3. Land Pollution Control and Solid Waste Management

Assignment for 1984 "Checklist for Inspection of Hazardous Waste Landfills for Disposal of Railroad Waste" was published in the May 1985 Bulletin under title of "Guide for Evaluation of Hazardous Waste Treatment, Storage and Disposal Facilities." The 1985 assignment entails extensive revision to Part 3 of Chapter 13 and a draft table of contents for these revisions has been finalized for further work in 1986.

4. Noise Pollution Control

Assignment for 1984 "Survey Railroad Workplace Noises to Recommend Engineering Technology for Noise Abatement *was not* accepted for manual publication. Rather it appeared as a manual recommendation in Bulletin 699 of January 1985. Mr. L. T. Cerny provided Board of Directors reasons for not publishing as Manual materials at the present time and the sub-committee has been involved with adjustments to ensure manual publication. Further development of previously published Bulletin information on noise barrier is planned for 1985 as possible manual material.

5. Plant Utilities

Assignment for 1985 involved extensive revision to Part 5 entitled "Plant Utilities - 1975" and entailed the inclusion of sections from old Part 4, Industrial Hygiene and Part 6, Corrosion Control.

A rough draft of Part 5 manual revisions has been completed and will be further refined during 1986.

B. Research Needs

Committee 13 considers that research needs are being adequately met through the activities of the Environmental Committee of A.A.R. A research needs survey from that Committee placed a very high priority on hazardous material spill response and cleanup; together with related problems of oil and hazardous material ground water contamination. New hazardous waste regulations may remove some railroads from the small quantity generator protection so that this may become a matter of higher priority. Regulations will ultimately require pre-treatment of hazardous wastes prior to disposal and may assume higher priority for some companies. Committee 13 will monitor this aspect of waste handling closely, with a view of establishing possible research requirements for in-house pre-treatment.

Excerpts From 1985 Annual Report of A.R.E.A. Committee 14 - Yards and Terminals

M. J. Anderson, Chairman

Subcommittee Activity

Subcommittee A:

Recommendations for further study and research.

Items that are being considered for new subjects and will be further reviewed at our October meeting are:

1. Control of contaminated wheels in hump yards.
2. Double stack containers in hump yards.
3. Design of vehicle loading and unloading facilities.

Subcommittee B:

Subjects that were submitted for manual revision this past year were:

Subcommittee 1 - "Fire Prevention in Yards."
Subcommittee 3 - Complete revision of Chapter 14, Part 6 - "Passenger Facilities."

Subjects that are being reviewed for revision to manual are Subcommittee 5 - Design of TOFC-COFC facilities to update Part 4 Specialized Freight Terminals 4.2 "Rail Truck," Subcommittee 6 - Guidelines for construction of walkways and inspection roads in classification yards, Subcommittee 7 - Local Yards - Development of Material for Section 2.3.5 of the Manual.

Subcommittee 1: Fire Prevention in Yards

This subject has been completed and upon printing, it will be recommended to drop this subject.

Subcommittee 2: Bulk Handling Systems

Chairman Zaenger has advised he will have a full report at our October meeting.

Subcommittee 4: Procedures for Handling Cars not to be Humped

This report is being corrected for latest comments and soon will be submitted for bulletin publication and then recommended to be dropped.

Subcommittee 5: Design of TOFC-COFC facilities

This subject was submitted and published as information in Bulletin 696, Page 157-190. Subject is being reviewed for revisions to Section 4.2 Rail-Truck and will be submitted in 1986.

Subcommittee 6: Guidelines for Construction of Walkways and Inspection Roads in Classification Yards

This report will be submitted to publish as bulletin information and then reviewed to determine what portions, if any, should be submitted as manual revisions.

Subcommittee 7: Local Yards - Development of Material for Section 2.3.5 of the Manual

This subject has incurred some delay but should be submitted for manual revision in 1986.

Subcommittee 8: Run-Through Trains Effect on Yards

John Szymkowiak is a new chairman replacing Frank Bartunek as he assumed all of Mr. Bartunek's duties on the Canadian National. This subject should show some progress with the assignment of a new chairman.

Subcommittee 9: Collaboration with the Transportation Research Board (TRB) Committee on Rail Freight Classification Terminal Design

The TRB committees on Rail Freight Classification Terminal Design and Intermodal Terminal Design are planning a conference on design of intermodal terminals, to be held in New Orleans in March of 1986.

Excerpts From 1985 Annual Report of A.R.E.A. Committee 15 - Steel Structures

C.R. Wahlen, Chairman

Committee Assignments

The following is the status of Committee Assignments:

File

AREA Assignments for Investigation and Report

R-71 A. Recommendation for further study and research:

This standing committee is chaired by the Vice Chairman and is developing recommendations which are to be structural in a format similar to that used by the Transportation Research Board.

R-3B B. Revision of Manual

This standing committee completed work on, and presented to Committee 15 for review and adoption, a four page recommendation entitled "Guidelines For Format of Chapter 15 - A.R.E.A. Manual." These guidelines were distributed to all Committee 15 members for consideration and comment.

R-7A
R-22
1. Develop specifications for the design of elastomeric bearings in Collaboration with Committee 8.

There has been an exchange of proposed specifications with Committe 8. The primary specifications will continue to be in Chapter 8 with those considerations for use with steel structures being covered in appropriate sections of Chapter 15.

R-91
2. Obtain data from which the frequency of occurrence of maximum stress in steel railway bridges may be determined under service loading.

Loading data has been obtained from twelve railroads, in three categories: Main Lines, Secondary Lines and Branch Lines. The subcommittee assembled the data and plotted loads versus frequency and prepared a series of graphs for comparison. The data was turned over to Dr. John W. Fisher of Lehigh University whose student, Mr. Scott Beisler has written a Master's thesis on "Frequency of Loading in Railroad Bridges." Copies of this thesis have been furnished to all subcommittee members for review and discussion at the October committee meeting.

R-97
R-22
4. Develop specifications for the earthquake design of steel railway bridges.

The proposed text for earthquake design for Chapter 15 has been sent to Committee 8 for review and collaboration.

R-99
5. Establish criteria for determining serviceability of steel structures which have been exposed to fire.

Article 8.6 "Guidelines for Evaluating Fire Damaged Steel Railway Bridges" has been amended, principally to simplify the temperature table, and published in the Manual. A. subsequent revision to add a color/temperature table has been approved by the Committee and submitted for publication. The committee recommends that this subject remain open in order to receive and review comments on the "Guidelines."

R-72
7. Bibliography and technical explanation of various requirements in AREA Specifications relating to iron and steel structures.

Editorial changes to Part 9 of Chapter 15 have been completed and sent to AREA Headquarters for publication.

R-100
R-93
8. Fracture Control Plan

A letter ballot has been submitted to the Committee membership to update the Specifications in accordance with current ASTM A-709. The results will be reviewed at the October, 1985 meeting.

Committee 15 Assignments

R-4
Welded Steel Bridges

Editorial changes have been submitted in order to have AREA Chapter 15 and AWS D1.1 support one another with compatible specifications.

R-9
Movable Bridges

A letter ballot has been submitted to the Committee membership to revise subarticle 6.2.10(b). The results will be reviewed at the October, 1985 meeting.

R-11
Rating

The subcommittee will discuss and review with Dr. John Fisher of Lehigh University research regarding the effects of fatigue on older riveted structures at the October meeting.

R-5 A new AREA assignment number 3 is recommended by Committee 15 - "Steel fabrication - materials, methods, quality control procedures and qualification of fabricators." With a reduction in the number of domestic fabricators and the inroads by foreign firms, there is a need to review our present specifications toward the goal of achieving quality assurance in steel fabrication.

Excerpts From 1985 Annual Report of A.R.E.A. Committee 16 Economics of Plant, Equipment and Operations

R. L. McMurtrie, Chairman

Your committee reports on the following subjects:

B. Revision of Manual

This subcommittee will review reports submitted for information for manual material. At the present time this subcommittee is studying material proposed by the various committees in the hope that material will be submitted for manual inclusion in 1986.

1. Economics of New Railway Terminal Location and Operation in Cooperation with Committee 14

A report titled "Economics of a Proposed New Classification Yard" was published as information in Bulletin 701, issued in May 1985. The next task under this assignment is to report on the "Effects of the Changing Nature and Patterns of Traffic on Terminal Economics." An outline has been completed from which assignments are being made to complete various portions of the report. Completion of this report will terminate Assignment 1.

2. Engineering Economics as an Element in Railroad Decision Support Systems

A report is being developed on methodologies for project evaluation. Project includes termination of base cases, benefit evaluation including safety and nonfinancial benefits, and discounted cash flow analysis (net present value and internal rate of return).

Computational aid for perfoming discounted cash flow analysis are surveyed. It is anticipated that this assignment will be completed in 1986.

3. Economics of Train Speed

Train speed is being studied in context with effects on the system, car scheduling, and the market. An expanded outline has been prepared which includes Preface, Analysis, Effects on Car Schedule Time, Projected Traffic, Benefits of Increased Train Speed, Costs of Increased Train Speed, and Balancing Benefits and Costs. Based on this outline subcommittee members are now contributing to a draft of the report. We anticipate completing this report in 1986.

4. Economics of Automatic Train Inspection Equipment and Location, including Consideration of Unattended Rear of Trains.

The previous industry survey on "End of Train" devices was inconclusive, possibly because the state of the art at the time was quite new. A new survey has been drafted and will be distributed to various railroads through committee members. The "End of Train" problem is the first phase of this assignment which will delve into many other potential train inspection methods.

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

The subcommittee has drafted the start of a report and work will continue on information collection, analysis and report preparation.

6. Applications of Industrial Engineering to the Railroad Industry

This is a continuing assignment under Committee 16 in which the subcommittee is concentrating on a series of reports dealing with the application of specific industrial engineering techniques in the railway industry. A report on "Applications of Standards for Budgeting in Railways" was published as information in Bulletin 701, issued in May 1985. The subcommittee is presently involved with a study of "Applications of Robots in Railways" which is being done in conjunction with M.I.T.'s robotic research group.

Excerpts From 1985 Annual Report of A.R.E.A. Committee 22 Economics of Railway Construction and Maintenance

G. Liljeblad, Chairman

Progress on subcommittee assignments for the Year 1984-85 is as follows:

Subcommittee A - W.C. Thompson, Chairman

"Recommendation for further study and research"

New approved subjects:

1. Economics of track stabilization upon high speed track surfacing operations. Assigned to Subcommittee No. 8, A. E. Shaw, Chairman.

2. Develop economics of methods to dispose of scrap and obsolete materials (O.T.M., rail, etc.). Assigned to Subcommittee No. 2, R. W. Simmons, Chairman.

Subjects submitted for approval:

1. Economics of various surfacing gang consists used by railroads in North America. Assigned to Subcommittee No. 3, E. C. Allen, Chairman.

2. Economics of various fixations of rail to wood ties. Assigned to Subcommittee 9, N. C. LaRocco, Chairman.

Subjects to be dropped:

1. Develop methodology to compare railroad maintenance-of-way costs - Subcommittee No. 5, P. Fatula, Chairman. This subject proved too nebulous to handle effectively. Correlation of data from various railroads is not possible at this time due to different accounting practices and non-uniform data bases.

2. Economics of per diem costs versus camp cars/semi-fixed headquarters versus fixed headquarters; both camp cars and headquarters requiring company transportation to work site. Our attempt to devise a questionnaire for gathering data on this subject was not successful. The many variables involved in the labor agreements and maintenance practices of the railroads proved too complex.

Subcommittee B

Proposed revision of Chapter 22, Part 2, of the Manual is currently in process of review and letter ballot by the Committee, and will be forwarded to Headquarters by December 1, 1985.

Revision of Chapter 22, Part 3, is continuing, with expected completion in 1986.

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

The subcommittee is preparing a report on the tamping and ballast maintenance demonstration on the Chessie System trackage at Chesapeake, Virginia, June 18, 1985, wherein the Plasser continuous motion tamper and other equipment worked for the benefit of the Committee.

Subcommittee 2 - "Economics of highway grade crossing renewals"

This subject was completed and report submitted for publication as information. The new subject assignment is "Develop economics of methods to dispose of scrap and obsolete materials."

Subcommittee 3 - "Economic use of geotextile fabric in new construction and track rehabilitation"

Subject is completed and report submitted for publication as information. The new subject assignment is "Economics of various surfacing gang consists used by railroads in North America."

Subcommittee 4 - "Economics of ballast cleaning"

A questionnaire has been developed and approved by the Committee. Circulation to the member roads will occur in 1985 and completion of the subject is expected in 1986.

Subcommittee 5 - "Develop a methodology for comparing railroad maintenance-of-way costs"

As previously stated, this subject is recommended to be dropped. No new subject has been assigned as yet.

Subcommittee 6 - "Economics of shop butt welding 39-foot rails versus long rail (78-80-foot rails) into CWR strings"

A questionnaire was circulated to the member roads after approval by the Committee. Completion of this subject is expected in 1986.

Subcommittee 7 - "Economics of laying welded rail directly on ties in new construction versus laying panels first and then changing jointed rail out and replacing with welded rail"

The work on this subject is complete and report submitted to headquarters for publication as information. No new subject assignment has been made as yet.

Subcommittee 8 - "Economics of the usage of track stabilization upon high speed track surfacing operations"

This is a new subcommittee and seven members volunteered to work on the subject.

Subcommittee 9 - "Economics of transporting maintenance-of-way gangs"

The above subject was completed and report submitted for publication as information.

A new Subcommittee Chairman was appointed, Mr. N. C. LaRocco, and the subject for study is "Economics of various fixations of rail to wood ties."

Excerpts From 1985 Annual Report of A.R.E.A. Committee 24 - Engineering Education

D. V. Sartore, Chairman

III. Subcommittee Reports

Subcommittee A - Recommendations for Further Study and Research

The committee recommends continuation of Subcommittee A - Further Study; Subcommittee 1 - Recruiting and Speakers; Subcommittee 3 - Curriculum Development; Subcommittee 4 - Student Relations; Subcommittee 5 - Continuing Education; and Subcommittee 6 - Faculty Support. No further assignments are contemplated at the present time.

Subcommittee 1 - Recruiting and Speakers

This subcommittee has made a survey and prepared a report of college graduate hiring by the Maintenance of Way and Structures Department of member railroads for calendar year 1984. This should be published in an upcoming bulletin. The survey, based on a questionnaire to Chief Engineering Officers, addresses degree and major of study, school, and salary. This survey is done annually and if further information is deemed to be advisable it will be added to the survey in future years.

A second part of this subcommittee's work is in arranging for speakers at universities, especially through ASCE Student Chapters. A letter has been drafted and will soon be sent to the student advisors of all ASCE Chapters explaining to them how they may request speakers from the railroad industry to address their students. Committee 24 asks that all railroad employees, particularly Chief Engineering Officers, honor requests for such speaking engagements either personally or by making arrangements for members of their staff to do so. The professors on the committee have assured the railroad members that such speaking appearances greatly enhance the railroads' opportunity to attract talented young engineers after they graduate. The letter also solicits Student Affiliate Memberships and mentions the proposed AREA scholarship program.

Subcommittee 3 - Curriculum Development

There has not been much activity on this new subcommittee due to the fact that its chairman had previously been placed in charge of the Seminar being sponsored by Committee 24 at the 1986 Technical Conference, which is taking most of his available time. Thus far the only work done by subcommittee 3 has been toward planning a course of action for it to follow to achieve its goal of influencing the universities to be more responsive to railroad educational needs.

Subcommittee 4 - Student Relations

This subcommittee, which has been responsible for coordinating the design contests and technical paper competitions for undergraduate college students in the past, will now be coordinating the AREA Scholarship Program. The Board of Direction has discontinued the contest/competition program effective in 1985, and plans to award five scholarships annually, each valued at two thousand dollars beginning in 1986. The details, such as eligibility, application requirements, evaluation of applications, etc., have been worked out and are ready to be implemented next year.

Subcommittee 5 - Continuing Education

Plans for the committee sponsored seminar following the 1986 Technical Conference are progressing. Subjects have been chosen, lectures have been contacted, and the details that the headquarters staff will handle have been determined. The AREA headquarters staff has been authorized to award Continuing Education Units (C.E.U.'s) for AREA functions such as seminars, field trips, technical conferences, etc. This will greatly assist those engineers registered in Iowa to obtain the credit necessary to remain registered. Incidentally, several other states have been considering similar requirements to maintain registration.

Subcommittee 6 - Faculty Support

The subcommittee has been active in setting up a process to furnish University professors with materials that can be used to assist in teaching railroad engineering subjects. A survey (by questionnaire) of professors produced a list of desired materials, such as engineering reports, designs, computer programs, etc. This list was then mailed to Railroad Chief Engineering Officers, and to Consulting Engineering firms with a request that they advise what materials they would be willing to furnish. The replies are now coming in. A list of available materials will then be sent to the Universities, and upon request, AREA headquarters will reproduce and send to them whichever items they can use in their classrooms to provide a basis for railroad related engineering problems to their students.

IV. Remarks

The committee wishes to express its appreciation to the Board for the support it has provided in the past several years. It has confirmed the committee's feeling that the present Board does share the opinion that the committee on Engineering Education is important, an opinion the committee felt had not been adequately projected in some past years.

Excerpts From 1985 Annual Report of A.R.E.A. Committee 27 - Maintenance of Way Work Equipment

G. D. Williams, Chairman

Report on Subcommittee Assignments

Subcommittee A - Recommendations for Future Study and Research

This committee continues to canvass members in an effort to develop interesting and meaningful topics for discussion and subsequent publication.

Subcommittee B - Revision of Manual

The revised specifications for on-track roadway machines was published in AREA Bulletin 699. As of the last meeting, the committee had made no decision on further work with manual revision.

Subcommittee 1 - Preventive Maintenance

This subcommittee continues its efforts in testing various items of equipment and related components such as tamping tools, drill bits, etc. It has been recommended by Mr. Rush that more in-depth testing be done. This subcommittee's members will have to work closely together to insure that anti-trust guidelines are followed. We are concerned that the costs to develop more thorough test results may become so high that individual roads may not participate in these tests. If AREA or AAR has funds available for Committee 27 use, we would want to be included for future consideration.

Subcommittee 2 - Preventive Maintenance of M/W Equipment

A report developed by Subcommittee 2 was published in Bulletin 701. This subcommittee continues to make excellent progress in its efforts to provide valuable information to the industry.

Subcommittee 3 - Functional Life of M/W Equipment

This subcommittee also had a report published in Bulletin 701. With this second publication, it was felt that the work of this committee was complete.

Subcommittee 4 - M/W Equipment Safety

Subcommittee 4 will continue to provide information and guidance on deficiencies in maintenance of way equipment. Equipment safety is an ever-increasing area of concern to the industry. This subcommittee will continue in its efforts to develop safety standards for M/W equipment.

Subcommittee 5 - Training Programs for Machine Operators and Maintainers

The lack of good training aids appears to be a problem that has not been easily resolved. Many of the larger railroad companies have adequate resources to meet their training needs. The majority of the carriers must rely on programs offered by the manufacturers. We have recently determined that VHS is the most desirable presentation medium. This committee will continue to work with the manufactures in an effort to provide an adequate product for the railroads.

Subcommittee 8 - Future Equipment Needs

Subcommittee 8 continues to collect data from engineering department heads in an effort to advise manufacturers on equipment requirements. It is our intent to continue this study on an on-going basis.

Subcommittee 9 - Noise Reduction on M/W Equipment

This subcommittee has provided members with noise levels of various types of work equipment, safety stickers and other information related to noise levels. The chairman has recently resigned and as of this date, a new chairman has not been appointed. We feel that this area of investigation should continue into 1986.

Excerpts From 1985 Annual Report of A.R.E.A. Committee 28-Clearances

D. J. Moody, Chairman

Subcommittee "A" - "Recommendations for further study and research."

New subjects being explored by the committee are:

1. Develop a format so that shippers can establish better lines of communication for obtaining more detailed information on shipments.

2. Investigation of possible legal problems involving rail carriers using customer-owned tracks; possibly explore establishing clearance requirements in track agreements.

Subcommittee "B" - "Revision of Manual."

The manual was revised to reflect the following:

A. Pages 28-3-1 and 28-3-2 were printed. These pages were approved for publication earlier but were not included in the manual.

B. Section 3.8 "Definitions of words used in railroad high and wide clearances" was added. These definitions appear on pages 28-3-27 to 28-3-32.

C. Chapter 28 index pages i and ii were revised.

Material in the manual is being reviewed for revision. Changes in the A.A.R. Mechanical Division Equipment Plates will necessitate revision of pages 28-2-1, '-3, '-6 and '-7 of the manual.

The needed revisions will be submitted to headquarters for inclusion in 1986 manual revisions.

Subcommittee 1 - "Review *Railway Line Clearances* to develop improved user accessibility."

The first tasks of this subcommittee are (a) study height and width configurations for purpose of reducing overall number of columns in the publication and (b) inclusion of heavy-duty car section in the *Railway Line Clearances (RLC)*.

The proposed revisions are primarily contingent upon computerization of the *RLC*. Committee 28 is working with National Railway Publication Company to determine an appropriate computer format and retrievability considerations. The computerization of *RLC* should be in 1987. When this task is completed the Committee will work on reducing the number of columns in *RLC*.

Inclusion of the heavy-duty car section in the *RLC* is being discussed.

Subcommittee 2 - "Compilation of the railroad clearance requirements of the various states."

All fifty-one (51) of the governmental bodies shown on page 28-3-23 of the manual have been contacted. The chart in the manual is entitled: "Legal Clearance Requirements by States". It contains legal clearance requirements for all states (except Hawaii), the District of Columbia and Canada.

The status of the subcommittee's work is:

39 replies have been analyzed and are being reviewed by the Committee.

11 replies have been analyzed but not sent to Committee as of September 4, 1985.

1 reply is on-hand but not analyzed by subcommittee as of September 4, 1985.

Of the 50 governmental bodies that have replied, 31 have had changes. It is planned to submit whatever information the subcommittee has developed by September 16, 1985 to the membership for approval. It is anticipated that the Committee will send its recommendation to headquarters by October 10 for Board approval, bulletin publication and 1986 manual revisions.

Subcommittee 3 - "Investigate the criteria for handling heavy and excessive dimension shipments, collaborating as necessary or desirable with Committees 5, 7, 8 and 15."

The subcommittee has prepared a booklet entitled: "Recommended Practice for Measuring Excess Dimension Loads."

The Committee is voting on the booklet. Concurrently, Committees 5, 7, 8, and 15 are being solicited for comments. Also, comments are being solicited from members of the A.A.R. Open Top Loading Rules Committee and the Car Department Officers Association. It is anticipated that the Committee will send its recommendations to headquarters by October 10 for Board approval, bulletin publication and 1986 manual revisions.

In addition, the Committee recommends that the publication be published by AREA.

Subcommittee 4 - "Conversion of 'Heavy Capacity and Special Type Flat Car' Section of *The Official Railway Equipment Register* (ORER) to UMLER compatibility format."

This is a new assignment suggested at Committee 28's February 1985 meeting. It was approved by the Board for a new assignment in April 1985. This assignment was prompted by a request from an *AAR UMLER Subcommittee* for Committee 28 to consolidate and simplify where practicable the narrative notes into alpha, numeric or alpha numeric codes for use in the UMLER data base. Originally, it was felt that the subcommittee's work would be only for six months. At this time it appears that work will continue into 1986.

To date items reviewed have been:

A. Platform Height Above Rail, Card 2, Positions 45-48. Use current UMLER specifications.

B. Center of Gravity (Empty Car), Card 3, Positions 55-57. Use current UMLER specifications.

C. Truck Center Length, Card 3, Positions 45-48. Recommend that owners of cars exceeding 76'-11" (4 cars currently recorded report them in the exception file (Z) where specific lengths can be shown.

D. Nominal Capacity, Card 3, Positions 24-26. Upper limit for nominal capacity will be increased from 700(000) to 800(000) effective January 1, 1986.

E. Number of Axles, Card 3, Position 50. Field will be made alpha numeric so as to accommodate 4 through 36 axles per car effective January 1, 1986.

F. Total Allowable Weight on Rail, Card 3, Positions 41-43. Need to develop correlation among maximum load, number of axles and journal size.

G. Wheel Size, Card 3, Position 52. Need to define standard wheel diameter for a car.

H. Truck Type and Axle Spacing, Card 3, Position 51. Listing of car with 6 or more axles has been made from the heavy duty car section in ORER.

I. Notes, Card 4, Positions 21-23. Developed breakdown of note types for 125 notes listed in heavy duty car section *ORER*. Committee 28 is investigating the usage of current notes. From April through July 1985 the number of cars showing notes was reduced from 114,000 to 40,400. We believe this field will be available for heavy duty car notes.

The Committee recommends the following:

1. Make recommendations to standardize the information as it now exists in *ORER*.

2. Continue to work on creating the *ORER* heavy-duty section completely from UMLER data fields.

3. Study the *ORER* heavy-duty section in order to make useful changes or additions to be included in UMLER.

4. Study the possibility of listing all heavy duty cars in *ORER* heavy-duty section including the private-owner cars.

Subcommittee 5 - "Research and develop book covering heavy-duty diagrams and ratings."

The subcommittee is doing the following:

A. Prepared diagrams and received owner's concurrence for most railroad-owned 6-axle depressed FD-type flat cars.

B. Prepared moment and shear tables for cars completed in Item A.

C. Preparing diagrams for railroad-owned 8-axle FD-type cars.

D. Upon completion of 8-axle FD's will start diagrams for railroad-owned FM 4, 6, and 8-axle cars.

E. Presently also preparing diagrams for privately-owned cars of various types.

F. Will start in September 1985 on U.S. Department of Defense car diagrams.

G. When railroad owned 4, 6, and 8-axle heavy-duty car diagrams are completed, will prepare diagrams for 10 and more axle FM and FD cars.

H. Concurrently as diagrams are done the moment and shear tables will be prepared.

It will take another two years to complete this assignment; however, the assignment should be permanent since the heavy-duty car fleet changes.

Subcommittee 6 - "Study the effects of shipment center of gravity in relation to train speed and track curvature."

A final decision has not yet been made concerning the proposed testing of high center-of-gravity shipments at the AAR FAST facility.

As suggested in the past, the actual testing of high center-of-gravity shipments is in order. The test should be conducted on tangent and curved track. There should be various classes of track. Since the industry is very interested in transporting containers in double-stacked configuration, it would be appropriate that high center-of-gravity testing be done first on container-type configurations. Another consideration for high center-of-gravity shipments is wind loads. The Committee recommends that testing be conducted at FAST. If there is no testing done, it may be in order to discontinue this assignment.

The Committee has the following recommendations for this assignment:

1. Complete a table of how different railroads handle high center-of-gravity shipments for possible publication as information in the AREA Bulletin.

2. Continue to accumulate available information on the subject of high center-of-gravity shipments.

Subcommittee 7 - "Committee for government and industry liason."

The subcommittee reports:

A. The Official Railway Equipment Register (ORER)

The AAR UMLER Committee is now studying the information for heavy capacity cars, and (ORER) is sending proof letters to both (ORER) Heavy Capacity proof recipients and to the individuals responsible for the UMLER submissions in order to resolve any discrepancies until a final determination can be made by the UMLER Committee.

An expanded listing of the DSI Rail Shipment Condition Codes was published in the April 1985 (ORER).

B. Railway Line Clearances (RLC)

The greatly expanded Glossary of Technical terms prepared by Mr. J. R. Strandberg (Committee 28 member) appears in the 1985 RLC booklet. In 1986 the Glossary will be near the front of the RLC book.

Four railroads merged and 3 went out of business, but 6 new railroads were added to the 1985 RLC.

The ambiguous page reference in the New Construction Diagram Section was clarified.

Rule 91 and Plate Diagrams in general were reviewed with the AAR immediately before going to press to insure use of the most current information.

C. The Official Intermodal Equipment Register (OIER)

Paul F. Kelly, Editor of the OIER, has been apointed head of the U.S. National Registration Organization by the Bureau International des Containers. Mr. Kelly is fluent in French, has attended the Bureau's meetings in Paris, and will be happy to assist in clearance problems involving containers.

D. Future - If desired by the Committee RLC is willing to publish an expanded Bibliography of Technical Literature and the contents of the Recommended Practice for Measuring Excess Dimension Loads booklet.

Subcommittee 11 - "Compilation of a comprehensive bibliography pertaining to the technical literature on railroad high and wide clearances."

Responses to the Glossary Ballot of February 1, 1985 have been received from 37 of 38 voting members (for that ballot) as of August 1. All definitions have passed by 81 percent. Two definitions that passed need to be discussed further due to substantive objections. If additional balloting is necessary it will be done. The definitions that are approved by October 1 will be sent to headquarters for Board approval, bulletin publication and inclusion in the manual.

Over 20 new definitions will be discussed and refined at the September 5 meeting. These will be submitted to the members for formal approval.

At least one new article will be published in the RLC editorial section.

Subcommittee 12 - "Recommended Procedure to insure that additions or modiications to clearances are promptly and properly reported to clearance engineer."

A draft procedure was prepared and reported on at the Committee's February 1985 meeting. The procedure was mailed to the full Committee for review and comments. As of late July, comments from a few members were received. We anticipate receiving more comments.

A report was made at the September meeting. A redraft of the procedure will be sent to members for final comments.

If necessary another redraft will be made and sent to the members for formal approval.

This assignment should be completed by the fall of 1986. At that time it will be submitted to headquarters for Board approval, bulletin publication, and included in the manual in 1987.

Excerpts From 1985
Report of A.R.E.A. Committee 32 - Systems Engineering

A.R. Hermann, Chairman

In regards to Committee 32's "Assignment for Investigation and Report", the following is submitted.

A. Recommendations for further study and research

Research interests of the Committee are listed below. At present, no request is made for funding for any specific program. For most of these subjects, research is already underway.

• New applications in the use of personal and mainframe computers for railroad engineering, construction, maintenance planning and business activities.

• Development of methods facilitating the exchange of information on computer programs.

Development of a library of available programs

Impact of corporate rules regarding information exchange

Legal implications of sharing computer knowledge and software.

• Improved data gathering techniques

• Utilization of information for the management of the engineering function.

B. Manual and Revision of Manual

No manual material or revisions have been produced for this reporting period. The Committee is reviewing an outline for a proposed manual chapter, however there is no documentation that is considered in final format for submission.

Subcommittee Activities

1. Administrative Systems . . . . . Disseminate information pertinent to the design and imple-

mentation, including specific applications or techniques within the scope of railroad engineering.

To better reflect the areas of interest and research being accomplished by Subcommittee #1, it is recommended that its title be changed to "Engineering Management Systems". A request to make this change will be submitted to AREA headquarters for consideration and approval.

A member of Subcommittee #1 has prepared a technical paper, "Managing The Fixed Plant." This document presents an analytical method to assist in the engineering management of the fixed plant assets. Subcommittee B is reviewing the document before final submittal to AREA. When submitted, it will be suggested to be published in the AREA Bulletin as a technical paper expressing the authors opinion.

3. Systems Engineering Education . . . . . Collect and disseminate information to the association membership by means of special features, seminars, demonstrations and printed material.

The recent technological developments that have made possible the production of low cost electronic computer systems have enabled individual purchasers to afford this type of equipment. Rapid acceleration in the availability and use of this equipment has resulted in a lack of timely information on computer components, programming and applications to railway engineering. The following subcommittee activities occurred during this reporting period to help alleviate this problem and introduce the AREA membership to "Personal Computer" applications.

- The subcommittee made a presentation on uses of personal computers in Railway Engineering at the AREA Technical Conference at Chicago, in March. A microcomputer exhibit was also included as part of this presentation.
- A two-day Symposium on "Personal Computers in Railway Engineering" was presented in Dallas, Texas, on September 16 and 17. A copy of the symposium program, including subjects and speakers is included as Attachment #1 to this report.

4. Provide interface for coordination of effort in railroad engineering systems.

Technical review panels are assembled when called upon to review reports or work relating to systems engineering in railway engineering. There has been no activity in this area during 1985.

5. Utilization of Track Geometry

To better reflect the areas of interest that remain following the establishment of Committee 2, (Track Measuring Systems) it is recommended that the title of Subcommittee #5 be changed to "Gathering, Coordinating and Utilization of Information for Management of the Engineering Function". A request to make this change will be submitted to AREA headquarters for consideration and approval.

Subcommittee #5 has redirected its research activities and will be concentrating on the examination of the type, sources and users of information that are available to support management systems used by the Engineering Departments and the railroad company as a whole. This will include data obtained by track measuring systems.

Excerpts From 1985 Annual Report of A.R.E.A. Committee 33 - Electrical Energy Utilization

K. M. Watkins, Chairman

Subcommittee #1 - Electrification Economics

An update of the 1976 report on electrification cost was finalized and published in the May edition of the bulletin. The published report represents a collation of a large volume of information from 12 other organizations that contributed to the report. The amount of work involved is not truly reflected by the size of the report. I would like to thank Mr. Schwarm and his subcommittee members for their tenacity and dedication in completing this task. It is my recommendation that this subcommittee continue to accumulate such public information that becomes available for a future update.

Subcommittee #4 — Catenary-Pantograph Systems

Section 4.2, "Catenary System Design Criteria" has been completed and published in the manual together with Section 4.3 which covers "Electrification Feeding and Sectionalizing Arrangements." The basic requirements for pantograph performance have been completed and will be published in Part 8 of the manual which covers "Locomotive Interaction with the Caternary." Whilst Part 8 was primarily concerned with the electrical noise and harmonic generation, it is logical to cover the mechanical interaction in the same part, this is recommended as Section 8.2.

The subcommittee is currently reviewing the particular aspects of safety in electrified territory that are different from non-electrical lines.

The foundation of catenary poles is a substantial part of the cost of a catenary system and the various different designs will be surveyed for suitable examples. Present criteria are set by building and local codes which are not necessary economic for the application. Mr. Shaw is to be commended for the progress of this subcommittee.

Subcommittee #5 — Signals and Communications

Preliminary draft of a potential journal article has been prepared for circulation around the subcommittee. This covers various signalling methods that are in use and considered suitable for electrified territory. This is in review by the subcommittee.

Subcommittee #6 — Power Supply and Distribution

Activity is directed towards the interface between sub-stations at the railroad and the main power grid. An outline of the proposed guidelines was expected to be in place this year, but due to pressure of commercial activities this has been delayed.

Subcommittee #7 — Contact Rails

No activity has taken place this year. At the March 1984 Committee meeting, it was agreed that contact rail applications were not typical of main line operation for freight, and that technology or information on this subject is available in the Transit and Light Rail Associations.

This subject will be covered in the manual by a reference list of available sources. When this is completed the activities of the subcommittee will be discontinued.

Subcommittee #10 — Equipment Generated Electrical Noise

Locomotive interaction with the catenary system is a complex subject. Part 8 has been completed and describes the electrical circuitry involved inside the locomotive, the purpose being to promote a better understanding of harmonic currents and interference generation. This is completed and approved by the Committee, and has been passed to H.Q. for inclusion in the manual.

Excerpts From 1985 Annual Report of A.R.E.A. Committee 34 - Scales

M.R. Gruber Jr., Chairman

Activities of our Subcommittees during the past year are as follows:

A. Recommendations for further study and research. Several innovations in the scale field have been brought to our attention. Action on one of these subjects was taken, and resulted in a special series of tests.

B. Revision of AAR "Scale Handbook." Most of the output of the Committee has been channeled to this subject. We have completed rewriting the AAR "Scale Handbook," and have begun making corrections. The results of our Committee's work, published as AAR "Scale Handbook" is included with other sections of the Manual as information. This Subcommittee has already begun to receive revisions which reflect new technology. Because the publication is looseleaf, supplementation is accomplished with ease.

1. Preparation of subjects for publication. This is a new Subcommittee whose purpose is to revise and edit all papers before submitting them to headquarters. As of this time, this Subcommittee has released one paper to headquarters, and expects to handle others in the near future.

2. Statistical data for coupled-in-motion weighing and testing. The Committee continues to receive requests for data on coupled-in-motion weighing from rail carriers and others. Also, on occasion the AAR has required some of the data. At the present time there is a law in all states allowing the use of one weight for unit trains. The rail carriers have taken the position that individual car weights must be shown. The primary reason is to detect overloads as well as to facilitate testing. The data available from this Subcommittee can be used when necessary to assist the railroads in their argument that such weights are necessary. A drive is presently on to bring the national list of track scales up-to-date, and to place this data on the AAR computer.

3. Innovations in scales used in connection with operations of railroads. This subject is intended to cover all new designs or types of scales. The Subcommittee will monitor weighing systems and keep the Committee informed.

4. Criteria for the location of coupled-in-motion track scales. The Subcommittee has been formed, and is at work writing a new set of suggested procedures to be followed by railroads, or others, who want, or are contemplating, a coupled in-motion scale.

5. Investigate tank car weighing. This subject was concluded with the report issued to headquarters for publication in the Bulletin. The committee would like to study light weighing of rail equipment as a new subject.

Special Committee on coupled-in-motion track scale tolerances. This Committee has been appointed to serve in conjunction with the National Conference on Weights and Measures, Specifications and Tolerances Committee, to develop new methods of testing, and possibly new reporting procedures. Several tests have been made utilizing special test procedures and forms and developed for this purpose. Additionally, a profile of the track and scale is required so that accurate comparisons may be made of similar type scales.

Special Committee on Kilo-Wate coupled-in-motion track scale. This Special Committee was furnished at the request of the scale manufacturer, and also at the suggestion of some of the Committee Members to test and evaluate this innovation.

Representation on the National Conference on Weights and Measures, Specifications and Tolerances, Special Committee on Belt Conveyor Scale Rules. The Committee was represented in several meetings on this subject which has resulted in the formulation of new rules which will become state law in virtually every state on January 1, 1986. Although this new law will contain some provisions which differ from the old law, the tolerances utilized by the rail carriers continue to be more strict and will be utilized by the railroad industry.

MANUAL RECOMMENDATIONS

COMMITTEE 1—ROADWAY AND BALLAST

Committee 1 has recommended revisions to Parts, 1, 2, 9, and 10 of Chapter 1. New Part 10 is titled "Geosynthetics".

Part 1's Table 1.2.5, "Soil Group, their Characteristics and Uses," on pages 1-1-32 and 1-1-33, is recommended to be expanded to include typical type geotextile fabric. This information should be useful in determining the required fabric for different type soils. A note is included which mentions that fabric will not improve a soil's classification.

Table 1.2.5
Soil Groups, Their Characteristics and Uses

	(1) Symbol	(2) Soil Group	(3) Field Identification	(4) Frost Heaving	(5) Drainage	(6) Value As Filter Layer
GRAVELS	GW	Well-graded GRAVELS and GRAVEL-SAND mixtures, trace to no silt or clay	Wide range in grain sizes, substantial amounts of all intermediate sizes, no dry strength	None to very slight	Excellent	Fair
GRAVELS	GP	Poorly-graded GRAVELS and GRAVEL-SAND mixtures, trace to no silt or clay	Predominantly one size, or a range of sizes with some missing, no dry strength	None to very slight	Excellent	Fair to poor
GRAVELS	GM	GRAVEL some SILT, GRAVEL-SAND-SILT mixtures	Fines with low or no plasticity, slight to no dry strength	Slight to medium	Fair to very poor	Very poor
GRAVELS	GC	GRAVEL some CLAY, GRAVEL-SAND-CLAY mixtures	Plastic fines, medium to high dry strength	Slight to medium	Poor to very poor	Not to be used
SANDS	SW	Well-graded SANDS and SAND-GRAVEL mixtures, trace to no silt or clay	Wide range in grain sizes, substantial amounts of all intermediate sizes, no dry strength	None to very slight	Excellent	Excellent
SANDS	SP	Poorly-graded SANDS and SAND-GRAVEL mixtures, trace to no silt or clay	Predominantly one size, or a range of sizes with some missing, no dry strength	None to very slight	Excellent	Fair to poor
SANDS	SM	SAND-SILT mixtures	Fines of low to no plasticity, slight to no dry strength	Slight to high	Fair to very poor	Very poor
SANDS	SC	SAND-CLAY mixtures	Plastic fines, medium to high dry strength	Slight to high	Very poor	Not to be used
SILTS & CLAYS OF LOW PLASTICITY	ML	SILTS, very fine SANDS, ROCK FLOUR	Fine grained, slight to no dry strength	Medium to very high	Fair to very poor	Not to be used
SILTS & CLAYS OF LOW PLASTICITY	CL	CLAYS of low to medium plasticity, CLAY-GRAVEL-SAND-SILT mixtures	Medium to high dry strength	Medium to high	Very poor	Not to be used
SILTS & CLAYS OF HIGH PLASTICITY	MH	SILTS, SILT-SAND mixtures of high plasticity	Slight to medium dry strength	Medium to very high	Poor to very poor	Not to be used
SILTS & CLAYS OF HIGH PLASTICITY	CH	CLAYS of high plasticity	Sticky when wet, high dry strength	Medium	Very poor	Not to be used
ORGANIC	OH	Organic SILTS or CLAYS	High smell, dark colour, mottled appearance, slight to high dry strength	Medium to high	Poor to very poor	Not to be used
ORGANIC	PT	MUSKEG, PEAT	Dark colour, spongy feel and fibrous texture	Slight to high	Poor	Not to be used

Adapted from ASTM Method D 2487T

COLUMN	NOTES
2	Soil types in capitals and underlined make up more than 50% of sample. Other soil types in capitals make up more than 10%
4	Tendency of soil to frost heave
5	Ability of soil to drain water by gravity. Drainage ability decreases with decreasing average grain size.
6	Value of soil as filter backfill around subdrain pipes to prevent clogging with fines, and as filter layer to prevent migration of fines from below.

	(1) Symbol	(7) Erosion On Exposed Slope	(8) Value As Subgrade	(9) Pumping Action	(10) Stability In Compacted Fills	(11) Compaction Characteristics	(12) Typical Duty Type Geotextile Fabric Use
GRAVELS	GW	None*	Excellent	None	Very good	Excellent, crawler-type tractor, rubber-tired roller, steel-wheeled roller	None Required
GRAVELS	GP	None*	Excellent	None	Reasonably good	Good, crawler-type tractor, rubber-tired roller, steel-wheeled roller	None Required
GRAVELS	GM	None to slight	Good	None	Reasonably good	Good with close moisture control, rubber-tired roller, sheepfoot roller	None Required
GRAVELS	GC	None to slight	Good	Slight	Fair	Excellent, rubber-tired roller, sheepfoot roller	None Required
SANDS	SW	Slight to high with decreasing gravel content	Excellent	None	Very good	Excellent, crawler-type tractor, rubber-tired roller	None Required
SANDS	SP	High	Good	None	Reasonably good with flat slopes	Good, crawler-type tractor, rubber-tired roller	None Required
SANDS	SM	High	Poor	None to slight	Fair	Good with close moisture control, rubber-tired roller, sheepfoot roller	Slight Regular
SANDS	SC	Slight	Poor	Slight	Fair	Excellent, rubber-tired roller, sheepfoot roller	Slight Regular
SILTS & CLAYS OF LOW PLASTICITY	ML	Very high	Poor	Slight to bad	Poor	Poor to good with close control of moisture, rubber-tired roller, sheepfoot roller	Yes Regular
SILTS & CLAYS OF LOW PLASTICITY	CL	None to slight	Bad	Bad	Reasonable	Fair to good, rubber-tired roller, sheepfoot roller	Yes Heavy
SILTS & CLAYS OF HIGH PLASTICITY	MH	None to slight	Bad	Very bad	Poor	Poor to very poor, sheepfoot roller	Yes Heavy
SILTS & CLAYS OF HIGH PLASTICITY	CH	None	Bad	Very bad	Fair with flat slopes	Fair to poor, sheepfoot roller	Yes Extra Heavy
ORGANIC	OH	Variable	Bad	Very bad	Not to be used	Poor to very poor	Yes Extra Heavy
ORGANIC	PT	Not applicable	Remove completely	Very bad	Not to be used	Compaction not possible	Yes Extra Heavy

COLUMN	NOTES
7	Ability of natural soil to resist erosion on an exposed slope. Soils marked * may be used to protect eroding slopes of other materials
8	Value as stable subgrade for roadbed, when protected by suitable ballast and subballast material. Good soils may be used to protect poorer soils in subgrade
9	Tendency of soil to pump up and foul ballast under traffic
10	Stability of soil against bulging and subsidence when used in a rolled fill. Cross check with Column (7) to forecast tendency to erode
11	Equipment listed will usually produce the required densities with a reasonable number of passes when moisture content and thickness of lift are properly controlled
12	Typical type Geotextile Fabric. Use is dependent upon existing or proposed subgrade design. Fabric will not improve soil classification. If additional strength is required, use enough stabilized material, granular base material, sub-ballast and ballast to properly span the weak subgrade soil

Part 2's revision is a new specification for ballast which replaces pages 1-2-1 through 1-2-6. It is the result of test data obtained in the laboratory, field testing and actual performance evaluation of various ballast materials in track. It represents the first general revision of the ballast specification in over 40 years. The foreword covers the history, trend and development of ballast. Mentioned is the ongoing current ballast tests which could improve the specification. Covered are materials, manufacture and their use. Terms used such as track superstructure, track sub-structure, ballast, sub-ballast, and roadbed are defined. Beneficial use is made of references to other, manual chapters. Tables of values for testing ballast material and gradations are included. A commentary mentions the high standards for quality track structure. It includes commonly used ballast materials, the creation of fines which could inhibit drainage, and the testing for quality ballast material. It states that the ballast for concrete tie installations must be limited to either crushed granites, traprocks or quartzites. Also, ballast graded larger than the A.R.E.A. No. 24 gradation has performed well on the Northeast Corridor concrete tie installations.

Part 2
Ballast

FOREWORD

In the early days of the U.S. Railroad Industry, a variety of materials were used for track ballast to support the track superstructure. Almost any ballast material which could be procured on line at a low unit cost was used and considered satisfactory under the traffic loadings. As rail loadings and speeds increased, track geometry deterioration became a problem for the industry.

Track geometric deviations and rail wear were recognized as major maintenance problems in the early teens. This resulted in the organization of a special joint committee sponsored by the A.R.E.A. and A.S.C.E. to study stress in the railroad track structure under the chairmanship of Professor A. N. Talbot. The committee immediately began their study of the track superstructure support, i.e., rails, cross ties, and fastenings. The study produced the "U" value as a measurement of vertical track stiffness as defined in the A.R.E.A. Bulletin, Volume 19, Number 205, March, 1918. The "U" value represents the stiffness of the track and involves conditions of the ties, ballast and roadway. Study of "U" values in the superstructure indicated that the influences of the track substructure (ballast and sub-ballast) were significant. Thus the need for better ballast materials became more obvious.

Extensive ballast material tests were conducted by Rockwell Smith of the A.R.E.A. during the middle fifties and sixties. The test results indicated that the ballast was an integral part of the track substructure and that support in the roadbed section has a direct relationship to the quality of the ballast materials.

Today greater demands are placed on the track superstructure and substructure. Heavier wheel loads, higher operating speeds and unit train consists demand better total performance of the track system. The improvement of the performance of the substructure appears to be an economical approach to increasing the strength of the track system.

More emphasis must be placed on the quality and type of ballast materials used in the substructure. Improved geotechnical techniques and test methods together with a better understanding of soils have provided the opportunity for ongoing tests to evaluate the quality and support characteristics of ballast materials.

During the past twenty year period, extensive ballast material tests have been conducted by the railroad industry, the railway supply industry, universities and some governmental agencies. This includes the ballast and roadway tests at the A.A.R. FAST Track.

From the results of these multiple material tests and performance evaluations, improved information has been obtained on the desirable physical and chemical properties of ballast materials which will provide performance characteristics commensurate with current track loadings and cost effective maintenance requirements of the track substructure.

The following Ballast Specification is the first general revision of the A.R.E.A. Ballast Specification in over forty years. The Specification is the result of the aforementioned test data obtained in the laboratory, field testing, and the actual performance evaluation of various ballast materials in track.

The efforts to produce a definitive ballast performance specification are not complete. A laboratory test to simulate performance and evaluation of ballast materials in track has not been developed. However; ongoing current ballast tests dedicated to the correlation of laboratory tests to field performance indicate that we may be approaching our goal. The results of these testing programs could dictate further improvement of the Ballast Specification in the future.

SUBSTRUCTURE

1.2.0 INTRODUCTION

1.2.0.1 DESCRIPTION

This part of these Specifications shall cover the design, materials, evaluation, production, construction and maintenance and evaluation of those components of the track structure which are situated above the soils or rock of the roadbed, or the wood, steel or concrete materials of the roadbed, installed for the purpose of providing support to the rail-crosstie arrangement of a conventionally constructed track system.

1.2.0.2 **NOMENCLATURE**

Within these Specifications, the following terms shall be defined as:

1.2.0.2.1 Track Superstructure - The assembly of rail, crossties, other track materials and special track materials which are the components of a conventionally constructed track system.

1.2.0.2.2 Track Substructure - The strata of granular materials that are installed for the purpose of:

A. Permitting drainage within the track substructure.

B. Anchorage of the track superstructure in the three dimensions of space.

C. Distribution of loads and transfer of the track superstructure loads to the underlying roadbed.

D. Facilitating fine adjustment of track superstructure alignment, grade and cross level without system reconstruction.

E. Shielding the materials of the roadbed from climatic forces.

1.2.0.2.3 Ballast - The upper stratum of the substructure upon which the superstructure is placed to a depth as defined by the individual railway company standards.

1.2.0.2.4 Sub-ballast - A lower stratum of the substructure beneath the ballast section located upon the roadbed to a depth as defined by the individual railway company standards.

1.2.0.2.5 Roadbed - That stratum of soil or rock which is constructed in accordance with Part 1 of this chapter which provides support for the track structure.

NOTE: Except for new construction, the boundaries between the strata, as defined, may not be distinct.

1.2.1 **DESIGN**

1.2.1.1 **BALLAST SECTION**

The ballast section shall be designed in accordance with requirements as outlined in the A.R.E.A. Manual Section No. 22.3.1 - 3.3.3 or as defined by individual railway company standards.

1.2.2 **SCOPE**

These specifications cover the types, characteristics, property requirements and manufacture of mineral aggregates for processed (prepared) ballast. Ideally processed ballast should be hard, dense, of an angular particle structure providing sharp corners and cubical fragments and free of deleterious materials. Ballast materials should provide high resistance to temperature changes, chemical attack, have high electrical resistance, low absorption properties and be free of cementing characteristics. Materials should have sufficient unit weight (measured in pounds per cubic foot) and have a limited amount of flat and elongated particles.

The type or types and gradations of processed ballast materials as covered in these specifications and testing requirements shall govern the acceptance or rejection of ballast materials by the Engineer, or as directed by the individual railway company.

1.2.3 **MATERIALS**

1.2.3.1 **TYPES OF MATERIALS**

A variety of materials may be processed into railroad ballast. The following general classifications and accompanying definitions list the most common materials. Detailed examination of individual materials should be made to determine the specific mineralogical composition.

1.2.3.1.1 Granite is a plutonic rock having an even texture and consisting chiefly of feldspar and quartz.

Definitions: A plutonic rock is rock formed at considerable depth by chemical alteration. It is characteristically medium to coarse grained, of granitoid texture.

1.2.3.1.2 Traprock is any dark-colored fine grained non-granitic hypabyssal or extrusive rock.

Definitions: Hypabyssal - Pertaining to an igneous intrusion or to the rock of that intrusion whose depth is intermediate between that of plutonic and the surface.

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

Definitions: Granoblastic - type of texture in a nonschistose metamorphic rock upon which recrystallization formed essentially equidimensional crystals with normally well sutured boundaries. Chert -A hard, dense cryptocrystalline sedimentary rock consisting dominantly of interlocking crystals of quartz.

1.2.3.1.4 Carbonate rocks are sedimentary rocks consisting primarily of carbonate materials such as limestone and dolomite.

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

1.2.4 **PROPERTY REQUIREMENTS**

1.2.4.1 **PHYSICAL ANALYSIS**

The methods of sampling and testing as defined by this specification are those in effect April 1985 and may be revised or altered by the individual railway company.

1.2.4.1.1 **METHOD OF SAMPLING**

Field samples shall be secured in accordance with the current ASTM Methods of Sampling, designation D 75.
Test samples shall be reduced from field samples by the means of ASTM C 702.

1.2.4.1.2 **SIEVE ANALYSIS**

Sieve analysis shall be made in accordance with ASTM Method of Test, designation C 136.

1.2.4.1.3 **MATERIAL FINER THAN NO. 200 SIEVE**

Material finer than the No. 200 sieve shall be determined in accordance with the ASTM Method of Test, designation C 117.

1.2.4.1.4 **BULK SPECIFIC GRAVITY AND ABSORPTION**

The bulk specific gravity and percentage of absorption shall be determined in accordance with the ASTM Method of Test, designation C 127.

1.2.4.1.5 PERCENTAGE OF CLAY LUMPS AND FRIABLE PARTICLES

The percentage of clay lumps and friable particles shall be determined in accordance with the ASTM Method of Test, designation C 142.

1.2.4.1.6 RESISTANCE TO DEGRADATION

The resistance to degradation shall be determined in accordance with the ASTM Method of Test, designation C 131 or C 535, using the grading as specified in Note #1, Table #1. Materials having gradations containing particles retained on the 1" sieve shall be tested by ASTM C 535. Materials having gradations with 100% passing the 1" sieve shall be tested by ASTM C 131.

1.2.4.1.7 SODIUM SULFATE SOUNDNESS

Sodium Sulfate Soundness tests shall be made in accordance with the ASTM Method of Test, designation C 88.

1.2.4.1.8 UNIT WEIGHT

The weight per cubic foot shall be determined in accordance with the ASTM Method of Test, designation C 29.

1.2.4.1.9 PERCENT OF FLAT AND/OR ELONGATED PARTICLES

The percent of flat and/or elongated particles shall be determined in accordance with U.S. Army Corps of Engineers test CRD-C-119.

1.2.4.2 CHEMICAL ANALYSIS

No specific chemical analysis is considered essential for the evaluation of granite, traprocks or quartzite type materials provided that the materials are properly defined by applicable methods. For carbonate materials, dolomitic limestones are defined as those materials which have a magnesium carbonate ($MgCO_3$) content of 28% to 36%. Those carbonate materials indicating magnesium carbonate values above 36% shall be defined as dolomites and carbonate materials indicating magnesium carbonate values below 28% shall be defined as limestones.

The magnesium carbonate ($MgCO_3$) content of carbonate materials shall be tested and defined in accordance with ASTM C 25.

Standard Methods of Chemical Analysis of Limestone, Quick Lime and Hydrated Lime, or other test methods as may be approved and directed by the Engineer.

Steel furnace slags consist essentially of calcium silicates and ferrites combined with fused oxides of iron, aluminum, manganese, calcium and magnesium.

Steel furnace slags having a content of more than 45% calcium oxide and/or a combined composition of more than 30% of the oxides of iron and aluminum should not be used.

Iron blast furnace slags consist essentially of silicates and aluminosilicates of calcium and other bases.

Iron blast furnace slags having a content of more than 45% of the oxides of calcium or a combined composition of more than 17% of the oxides of iron and aluminum should not be used.

1.2.4.3 LIMITING TEST VALUES

The following Table No. 1 outlines the limiting values of testing as may be defined by the designated test specifications. The values for unit weight and bulk specific gravity are minimum values while the remainder are maximum values.

1.2.4.4 GRADATIONS

The following Table No.2 outlines the recommended gradations to which the materials are to be processed for use as track and yard ballast. The grading of the processed ballast shall be determined with laboratory sieves having square openings conforming to ASTM specification E 11.

1.2.4.5 BALLAST MATERIALS FOR CONCRETE TIE TRACK INSTALLATION

The ballast materials as defined by this specification include the applicable test requirements for ballast materials for the purpose of providing support to the rail - cross tie arrangement of a concrete tie track system except that carbonate materials and slags as defined in Section No. 1.2.3.1 and gradation No. 57 as defined in Section 1.2.4.4 shall be excluded.

1.2.5 PRODUCTION AND HANDLING

The aggregate production facility shall be of such a design to permit production and or blending without excessive working of the materials and the facility must be approved by the purchaser. The capacity of the production facility should be adequate to efficiently produce the anticipated daily loadings providing sufficient stockpiles to facilitate loadings without any delays.

Blending, stockpiling and other production and handling operations shall be managed by the producer to minimize segregation of the finished product. Stockpiling operations shall minimize as practical the breakage or excessive fall in stockpiling operations and the movement of wheeled or tracked machines over stockpiled materials shall be limited.

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Table No. 1

Recommended Limiting Values of Testing for Ballast Material

Property	BALLAST MATERIAL: Granite	Traprock	Quartzite	Limestone	Dolomitic Limestone	Blast Furnace Slag	Steel Furnace Slag	ASTM Test
Percent Material Passing No. 200 Sieve	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%	C 117
Bulk Specific Gravity (See Note #2)	2.60	2.60	2.60	2.60	2.65	2.30	2.90	C 127
Absorption Percent	1.0	1.0	1.0	2.0	2.0	5.0	2.0	C 127
Clay Lumps & Friable Particles	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	C 142
Degradation	35%	25%	30%	30%	30%	40%	30%	See Note #1
Soundness (Sodium Sulfate) 5 Cycles	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%	C 88
Flat and/or Elongated Particles	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%	USACE CRD-C 119

Note #1 - Materials having gradations containing particles retained on the 1" sieve shall be tested by ASTM C535. Materials having gradations with 100% passing the 1" sieve shall be tested by ASTM C131.

Note #2 - The limit for bulk specific gravity is a minimum value. Limits for the remainder of the tests are maximum values.

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Table No. 2

Recommended Ballast Gradations

Size No.	Nominal Size Square Opening	PERCENT PASSING 3"	2½"	2"	1½"	1"	3/4"	1/2"	3/8"	No. 4	No. 8
24	2½" - 3/4"	100	90-100		25-60		0-10	0-5			
25	2½" - 3/8"	100	80-100	60-85	50-70	25-50		5-20	0-10	0-3	
3	2" - 1"		100	95-100	35-70	0-15		0-5			
4A	2" - 3/4"		100	90-100	60-90	10-35	0-10		0-3		
4	1½" - 3/4"			100	90-100	20-55	0-15		0-5		
5	1" - 3/8"				100	90-100	40-75	15-35	0-15	0-5	
57	1" - No. 4				100	95-100		25-60		0-10	0-5

Note #1 - Gradation Numbers 24, 25, 3, 4-A and 4 are main line ballast materials.
Gradation Numbers 5 and 57 are yard ballast materials.

Processed ballast shall be washed and/or rescreened as necessary to remove fine particle contamination as defined by the specification or as directed by the individual railway company prior to stockpiling in operations using stockpiles or immediately prior to loading operations.

1.2.6 LOADING

The manufacturer shall arrange the required supply of railcars, unless the purchase arrangement provides otherwise. The manufacturer shall assure the fitness of the cars for loading of the prepared materials, arranging to clean cars of deleterious materials, plug leaks and other like operations, as necessary.

Unless otherwise specified, rail cars shall be ballast cars furnished by the purchaser or hopper-type, or as designated by the Engineer.

1.2.7 INSPECTION

The railway company, or its representatives, reserve the right to visit the producers facility during usual business hours unscheduled for the following purposes:

a) Observe sampling and testing procedures to assure compliance with the requirements of these specifications.

b) Obtain representative samples of the prepared material being produced and shipped.

c) Review plant inspection, methods, quality control procedures, equipment and examine test results of current and previous tests.

The manufacturer shall provide the inspector with such assistance, materials, and laboratory testing equipment as necessary to perform on production site gradation and percent passing No. 200 Mesh Sieve analysis. Performance of these tests at the time of an unscheduled inspection visit is the right, but not the duty, of the inspector.

1.2.8 SAMPLING AND TESTING

The quality of a material to be used for ballast shall be determined prior to its acceptance by the purchaser. A series of tests as specified herein shall be made at a testing laboratory approved by the purchaser to establish the characteristics of the materials being tested.

Once a source has been accepted to supply ballast material, periodic quality control samples shall be taken to insure continued compliance with the specification. A representative sample of prepared ballast shall be taken for gradation from each 1000 tons of ballast being loaded for shipment. This sample shall be taken in accordance with ASTM D

75, and in the quantities as listed within that standard. A gradation report shall be prepared on each sample containing the following information: Source identification, date, sample number, shipment or car number, and the sieve analysis. The gradation specification shall appear on the test form.

In the event any two individual samples fail to meet the gradation requirement, immediate corrective action shall be taken to restore the production process to acceptable quality. The purchaser shall be advised in writing of the corrective action being taken. In the event of repeated failures, i.e., two or more samples failing in two successive shipments, the purchaser reserves the right to reject the shipment.

A full range of laboratory testing, as defined by this specification, shall be performed at least two times a year or as directed by the Engineer, to insure the quality of the material being produced. If the supplier changes the location of the source or encounters changes within the supply source, laboratory testing should be performed on the new material to ensure compliance with specifications.

Prior to installation, the supplier shall provide the Engineer with certified results of ballast quality and gradation as conducted by a testing laboratory accepted by the Engineer. The supplier shall receive approval of the Engineer for the Testing Laboratory prior to performing the aforementioned tests.

1.2.9 MEASUREMENT AND PAYMENT

Ballast shall be measured on a per ton basis and payment shall be made on the number of tons of acceptable materials furnished. No allowance will be made for moisture content of ballast materials loaded by any acceptable method. Weight tickets or records shall be maintained for a period of not less than six months for reference.

The number of tons shall be determined by one of the following methods and shall be approved by the purchaser:

a) Certified scale weights as determined by track scales (static or in motion weighing) truck scales or belt scales which load directly into the railcar.

b) Average weight agreements as mutually agreed upon by the purchaser and producer. The average net weight for each type and series of railcars shall be determined by the purchaser and producer to establish the average weight agreement per car. The average weight in the specified or type of cars shall be checked quarterly by the purchaser or as designated by the Engineer. The average weight will be calculated on lots of not less than ten (10) cars. The purchaser shall advise the producer if there is any variance in the average weight of the cars selected. The purchaser and the supplier will jointly make any changes in the loading methods to insure compliance with the weight agreement.

1.2.10 **MAINTENANCE PRACTICES**

1.2.10.1 **METHODS OF UNLOADING AND DISTRIBUTING BALLAST**

Ballast shall be unloaded and distributed as outlined in the A.R.E.A. Manual Section No. 22.3.3.3 or as defined by individual railway company standards.

1.2.10.2 **REPLACEMENT OF BALLAST AND IN TRACK CLEANING**

Replacement of ballast and cleaning shall be performed in accordance with the A.R.E.A.. Manual Section No. 22.3.2 or as defined by individual railway company standards.

COMMENTARY

Ballast is a selected crushed and graded aggregate material which is placed upon the railroad roadbed for the purpose of providing drainage, stability, flexibility, uniform support for the rail and ties and distribution of the track loadings to the subgrade and facilitating maintenance. There are distinct differences in the mineral composition of the various aggregate materials used for roadway ballast applications and the respective in track performance of those materials. Likewise, many variations exist in the mineral properties of aggregate materials within the same general nomenclature of the aggregates known as granites, traprocks, quartzites, dolomites, and limestones. One particular aggregate material may possess most of the desirable characteristics for a good ballast material while a deposit of apparently similar material located in the same general geographical area will not meet the applicable specification requirements for railroad ballast.

Thus, when selecting ballast materials it is necessary to define the type of material and the physical and chemical properties which can be measured in the laboratory by specific test methods. It is also most important to consider the field performance and behavioral characteristics of the ballast material in the roadbed section. Some of the properties which affect the field performance of ballast materials can be related to the crushing characteristics, hardness, durability, weight and other physical and chemical properties which are defined in the specification.

High standards must be established for railroad ballast to provide a quality track structure. Likewise, ballast required for concrete tie installations must exhibit some different behavioral and performance characteristics than those ballast materials which will provide satisfactory field performance for wood tie installations. Ballast is an integral part of the roadbed structure. The ballast section must react to track loadings in combination with the super-structure and sub-ballast to provide supporting strength for the track and roadbed commensurate with specific railroad loadings and operating requirements.

To provide track stability, the ballast must perform several well defined functions. The ballast must sustain and transmit static and dynamic loads in three directions (transverse, vertical and longitudinal) and distribute those loads uniformly over the subgrade. A prime function of the ballast is to drain the track system. The ballast must also perform a maintenance function to provide proper track alignment, cross level, and grade.

The most commonly used ballast materials today on the U.S. railroads are granites, traprocks, quartzites, limestones, dolomites and slags, which are defined in the specification. The specification does not limit the use of any rock type which can be processed into ballast when the material is properly defined and tested in accordance with the specifications and is approved by the engineer or purchaser. It is necessary; however, to warn the engineer that materials which tend to create fines will fill the voids between the particles and could inhibit drainage. Some of the powdery fines of carbonate materials have a tendency to cement together and a clogging action could occur.

The preferred ballast materials would be a clean and graded crushed stone aggregate and/or processed slag with a hard, dense, angular particle structure providing sharp corners and cubicle fragments with a minimum of flat and elongated pieces. These qualities will provide for proper drainage of the ballast section. The angular material will provide interlocking qualities which will grip the ties more firmly to prevent movement. Flat and elongated particles in excess of the maximum as specified in the specification could restrict proper consolidation of the ballast section. The ballast must have high wear and abrasive qualities to withstand the impact of traffic loads without excessive degradation. The stability of the ballast section is directly related to the internal shearing strength of the assembly of ballast particles. The material must possess sufficient unit weight (measured in pounds per cubic foot) as set out in the specification to provide a stable ballast section. The ballast must also provide high resistance to temperature changes, chemical attack, exhibit a high electrical resistance and low absorption properties. A ballast material should be free of cementing properties. Deterioration of thr ballast particles should not induce cementing together of the degraded particles. Cementing reduces drainage capabilities, reduces resiliency, and provides undesirable distribution of track loads and in most instances results in permanent track and roadbed deformations. Cementing also interferes with track maintenance.

Basically, all ballast materials are placed and tamped in the ballast section in accordance with similar maintenance practices. The materials are then subjected to basic loading patterns, however, there are several factors which will materially affect the in track performance and stability of ballast materials.

Drainage is the first and prime consideration in the roadbed maintenance and performance of a ballast material. Individual ballast particles must provide a free-draining and clean section for proper drainage of surface water to parallel side ditches or run off areas. Excessive moisture in subgrades and ballast sections are a primary source of track roadway problems. Side ditches should be free-draining and prevent standing water which could saturate the roadway subgrade. A wet ballast section reduces the shearing strength of the assembly of ballast particles and dirty, moist ballast sections will support the growth of vegetation which reduces the drainage capability of the ballast material. Drainage is a most important factor in contractive and expansive subgrade soil conditions which are prone to cause pumping conditions in the roadbed section.

Track loading patterns and traffic density, weight of the rail section, grades, the cross section of the ballast section, the sub-ballast and the roadbed interaction together with climatic conditions are major considerations in the performance of ballast materials. A well compacted subgrade and sub-ballast section will provide stable and uniform areas for the distribution of the track loads throughout the ballast section.

The quality tests as specified in the specification identify several physical properties and characteristics which are desirable for ballast materials. None of the tests considered on an individual basis, however, are indicative of the field performance one might expect from the material.

For instance, the test for friable materials (ASTM C 142) identifies materials which are soft and poorly bonded which will result in separate particles being detached from the mass. The test can identify materials which will deteriorate rapidly. Clay in the ballast material is determined by the same test method. Excessive clay can restrict drainage and will promote the growth of vegetation in the ballast section.

The Sodium Sulfate Soundness Test (ASTM C 88) is conducted with the test sample saturated with a solution of sodium sulfate. This test will appraise the soundness of the aggregate. Materials which do not meet applicable test limits can be expected to deteriorate rapidly from weathering and freezing and thawing. There is some preference for the Magnesium Sulfate Soundness Test, but there is insufficient historical data available for comparison to the Sodium Sulfate Soundness Test which has been used for many years.

The concentration of fine material below the 200 sieve in the ballast material is determined by the ASTM test method C 117. Excessive fines are produced in some types of crushing and processing operations and could restrict drainage and foul the ballast section.

Specific gravity and absorption are measured by test method ASTM C 127. Specific gravity in the English measurement system is related to weight and the metric system relates to density. The higher the specific gravity, the heavier the material. A stable ballast material should possess the weight limits as shown in the specification (Test Method ASTM C 29) to provide suitable weight and mass to provide support and alignment to the track structure. Absorption is the measurement of the ability of the material to absorb water. Excessive absorption can result in rapid deterioration during wetting and drying and freezing and thawing cycles.

The Los Angeles Abrasion Test is a factor in determining the wear characteristics of the ballast material. As directed in the specification, the larger ballast gradations should be tested in accordance with ASTM C 535 while ASTM C 131 is the wear test for smaller gradations. The Los Angeles Abrasion Test relates to the abrasive wear resistance of the aggregate. Excessive abrasion loss of an aggregate will result in reduction of particle size, fouling of the ballast section, reduction of drainage and loss of supporting strength of the ballast section. The Los Angeles Abrasion Test can, however, produce laboratory test results which are not indicative of the field performance of ballast materials.

Limestones are primarily calcium carbonate materials with small traces of other minerals. Calcium carbonates are a basic ingredient in the manufacture of cements and degraded carbonate fines have an experience of cementing together in the track structure when degraded particles are produced by track loads imposed upon the track structure and ballast section.

The performance of granites, traprocks and quartzites differ from that of the limestones when subjected to the same wear and abrasive loading conditions. Granites and traprocks can be coarse-to-fine-grained materials and degradation of these materials produces granular fines which do not induce cementing in the roadway.

The ongoing ballast and roadway tests at the FAST Track have also confirmed that the Los Angeles Abrasion Laboratory Test is not indicative of the field performance of ballast materials.

We must bring to the attention of the engineer that considerable variables exist with many laboratory physical testing methods and procedures and the Los Angeles test is no exception. Not only do variables exist between individual tests, but between testing laboratories as well. Studies conducted by ASTM Committee No. C9 (the committee responsible for the ASTM abrasion test methods and procedures) indicated that for nominal 3/4" maximum coarse aggregate with percentages of wear in the range of 10% to 45%, the multi-laboratory coefficient of variation is 4.5%. Therefore, the results of two properly conducted ASTM Los Angeles Abrasion tests from two different laboratories on the same sample of the same coarse aggregate could vary as much as 12.7%. ASTM C 131 defines this variable as a part of the Los Angeles Abrasion Test.

Likewise, the Sodium Sulfate Soundness Test is not at all precise, particularly in testing limestones. The test results may be affected significantly if the test solution has previously been used to test other carbonate rock samples. The test does provide the opportunity to develop relationships between various materials and will most certainly indicate the presence of shale in carbonate materials.

The variables in the aforementioned tests and the lack of correlation between the laboratory tests and field performance of ballast material are the prime reasons for ongoing research to develop laboratory tests which are indicative of field performance of ballast materials. The A.R.E.A. Ballast Committee is actively pursuing current ballast testing programs in conjunction with the railroads, the A.A.R, T.S.C., FAST and the railroad supply industry to develop laboratory tests to predict field performance.

BALLAST GRADATIONS

The gradation of a ballast material is a prime consideration for the in track performance of ballast materials. The gradation must provide the means to develop the compactive or density requirements for the ballast section and provide necessary void space to allow proper run off of ground water.

Ballast gradations should be graded uniformly from the top limit to the lower limit to provide proper density, uniform support, elasticity and to reduce deformation of the ballast section from repeated track loadings.

The A.R.E.A. mainline ballasts are graded in three sizes from 2 1/2" to 3/4", 2" to 1" and 1 1/2" to 3/4"; however, two additional gradations No. 25 and No. 4-A have been added to the specification to meet requirements of the railroads.

Rail yards and some industrial track gradations are generally graded from 1" to 3/8", (A.R.E.A. No. 5 gradation), to provide improved walkway and safety conditions along the track. The finer gradations for yard applications do not restrict track drainage as the construction practices for yard facilities provide quick run off of ground water through the means of under track and yard drainage systems.

A consideration in the selection of the proper ballast gradation is the selection of a ballast that will limit the amount of material removed from the track section during undercutting operations. Most undercutting operations remove all of the material below the 3/4" size. Limiting the amount of the 3/4" minus material in the original gradation will reduce the amount of ballast removed when undercutting operations are used to clean and restore the track ballast section.

The larger ballast gradations being used on the railroads today do not increase the cost of tamping. Mechanization has eliminated most of the necessity for manual labor in the roadway maintenance practices.

The type of ballast selected for use under concrete ties is a direct function of the track performance with the concrete tie. Extensive field tests of several designs of concrete ties have been installed on various types of ballast materials. The tests concluded that the loading characteristics of the concrete tie are quite different from the loadings imposed on wood ties on the same ballast cross section. Concrete ties which are heavier and less flexible to absorb impact loadings, transmit greater loads to the ballast section and thus create higher crushing loads on the individual ballast particles. Consequently, the selection of ballast materials for concrete ties must be very restrictive to provide satisfactory track performance. Ballast for concrete tie installations must be limited to either crushed granites, traprocks or quartzites.

A very important consideration is the selection of the proper gradation of the ballast material for concrete ties. The early concrete tie installations were placed on ballast materials graded to the A.R.E.A. No. 4 (1 1/2" - 3/4"), resulting in good in track performance, although other ballast materials graded smaller than the A.R.E.A. No. 4 gradation did not provide satisfactory support and restraint qualities. Concrete ties placed on ballast gradations smaller than A.R.E.A. No. 4 resulted in suspect performance in the first phase of the concrete tie tests conducted at the A.A.R. FAST test facility.

Two examples of very good performance of the A.R.E.A. No. 4 gradation is the granite ballast used for the concrete tie roadway on the Florida East Coast and the granite ballast used in the concrete tie test installed by the Santa Fe several years ago near Streeter, Illinois.

Concrete ties placed on gradations conforming to A.R.E.A. No. 3 (2" - 1") and A.R.E.A. No. 24 (2 1/2" - 3/4") have also exhibited good support qualities and performance characteristics during the second phase roadway tests at the FAST facility.

Likewise, ballast graded larger than the A.R.E.A. No. 24 gradation has performed well on the northeast corridor concrete tie installations.

SUMMARY

The A.R.E.A. Ballast Specification is intended as a guideline and cannot cover all of the requirements necessary for the full appraisal of the in track performance of a ballast material. It is not possible to incorporate into the laboratory tests those field factors which include geographical and climatic conditions, load variations, sub-grade conditions, and other conditions which will actually determine the total in track performance of a ballast material. Generally, the revised specifications have established material standards and test requirements which will provide more efficient ballast materials commensurate with current roadbed structure and performance requirements.

The A.R.E.A. Ballast Committee will continue to pursue the multiple ballast testing programs and will modify the ballast specification, as required, to produce a more definitive ballast specification for the railroad industry.

Part 9's revision is a new table, Types and Characteristics of Herbicides, which replaces the table on pages 1-9-14 through 1-9-21. Included is a brief introduction to the table at the bottom of page 1-9-13. Product brand names which appear in capital letters are intended only as an aid, not a recommendation, to the user. Reference is also made to "The Herbicide Handbook" published by The Weed Science Society of America.

Part 9
Railroad Vegetation Control

9.4.3 INTRODUCTION TO TABLE I - TYPES AND CHARACTERISTICS OF HERBICIDES

The herbicides listed by common (or chemical) name in Table I have been used substantially by member railroads as of the time of publication. Additional products may have found limited use. Product brand names appear in capital letters, and are intended only as an aid, not a recommendation to the user. More complete information is to be obtained from "The Herbicide Handbook", published by The Weed Science Society of America, 309 West Clark Street, Champaign, Illinois 61820.

I. SELECTIVE HERBICIDES

BROADLEAF CONTROL HERBICIDES

Common (or Chemical) Name:	2,4-D amine (2,4-dichlorophenoxy acetic acid)	2,4-D ester	2,4,5-T (not labeled for railroad use in the USA) amine or ester
Products and formulations available:	Commonly sold as 4 lb/gal equivalent Also 6 lb/gal true solution. Low odor formulations available as alkanolamine or diethanolamine salts.	Commonly sold as 4 lb/gal acid equivalent. Used in oil/water emulsion.	Commonly sold as 4 lb/gal acid equivalent in Canada & Mexico. Amine a true solution.
Herbicidal use: target species	Controls most broad-leafed annual and certain perennial weeds & vines.	Same as amine	Used primarily for brush control often with 2,4-D.
preemergent rate	Not recommended	Not recommended	Not recommended
postemergent rate	2-5 lb/a, higher rates required to control resistant species.	2-5 lb/a, higher rates required to control resistant species.	4-8 lb/gal for woody plants, volume determined by height & density.
Use precautions: flammability, corrosiveness, volatility, other.	Nonflammable, non-corrosive. Virtually nonvolatile. Should be sequestered against 800 ppm hardness of water.	Nonflammable, non-corrosive, volatile at higher temperatures (110°F or above). Hazardous to broadleaf crops.	Nonflammable, non-corrosive, virtually nonvolatile, amine may precipitate in water at 400-500 ppm hardness if not sequestered.
Physiological behavior & mode of action:	Entry primarily foliar, secondarily by roots. Translocated. Increases respiration and cell elongation.	Entry primarily foliar, less prone to wash off than amine. Mode of action same as amine.	Entry primarily foliar. Translocated. Mode of action similar to 2,4-D.
Soil behavior, mobility & persistance:	Salts of 2,4-D are leached in sandy soil, microbially degraded in 1-4 weeks.	Same as amine	Similar to 2,4-D but degraded more slowly.
Toxicology: acute LD50	500, Class 4 slightly toxic	Same as amine	300, Class 3 moderately toxic
Dermal Class other.	Mildly irritating Class 4	Same as amine	Mildly irritating Class 4
Other pertinent information:	Performs best when plants are growing rapidly. Do not apply within 4 hours of rain.	More effective than amine on hard-to-kill species, more hazardous to adjacent crops. Use in oil carrier.	Similar to 2,4-D amine and ester.

I. SELECTIVE HERBICIDES

BROADLEAF CONTROL (CONTINUED)

amitrol (not labeled for railroad use in USA)	fosamine ammonium	fenac	dicamba
Sold as water soluble powder, 90% active ingredient, AMIZOL, Union Carbide.	Sold as 4 lb/gal miscible liquid, 41.5% active ingredient KRENITE & Krenite S (with surfactant).	Sold as 1.5 lb/gal sodium salt, FENATROL Union Carbide.	Sold as 4 lb/gal BANVEL, & 1 lb combination with 2,4-D 2 lb/gal, BANVEL 720, Velsicol.
Perennial grasses & broadleafed weeds. Also many brush species.	Primarily for brush control adjacent to crops. Treated brush remains green.	Perennial broadleafed weeds and vines	Broadleafed weeds perennial vines & brush.
Not recommended.	Not labeled for use	4 lb/a on broadleaf annuals.	Activity at higher rates but not recommended.
2-4 lb/a on annuals, 4-10 lb. on perennials.	6-12 lb/a a.i. (1-1/2-3 gal/a), depending on brush density.	5-10 lb/a on woody vines & many perennials. Up to 20 lb on noxious weeds	0.5-10 lbs/a on broadleafed perennials & brush.
Nonflammable, mildly corrosive to Fe,Al,Cu and alloys, nonvolatile, true solution.	Nonflammable, mildly corrosive to copper nonvolatile.	Nonflammable, noncorrosive virtually nonvolatile, true solution.	Nonflammable, slightly corrosive, solubility 4500 ppm Volatile at high temperatures.
Entry foliar, translocated, inhibits chlorophyl formation and regrowth from buds.	Absorbed by foliage stems & buds of deciduous plants within 2 months prior to leaf drop. Limits bud formation.	Primarily root absorbed, translocated, otherwise similar to 2,4-D.	Both root and foliar entry, translocated, otherwise similar to 2,4-D. Hazardous to broadleaf crops.
Decompose in 14-21 days. Persistence not longer than 4 weeks.	Soil half-life 7-10 days, degrades rapidly preventing downward leaching.	Adsorped by soil colloids, resists leaching, biodegrades slowly from 1-2 years.	Mobile in soil, half life approx. 25 days.
2500, Class 4 Slightly toxic.	24,000, Class 5 Almost nontoxic.	3000, Class 4 Slightly toxic.	2900, Class 4 Slightly toxic.
Mildly irritating Class 4	Non-irritating. Class 5	Mildly irritating Class 4	Mildly irritating Class 4
Useful in combination with other herbicides	50-300 gal/a volume requiring complete	Generally used in combination with	Often used in combination with

I. SELECTIVE HERBICIDES

BROADLEAF CONTROL (CONTINUED)

Common (or Chemical) Name:	picloram	triclopyr amine	triclopyr ester
Products and formulations available:	Sold as 10% active pellet, TORDON 10K, 2 lb/gal K salt, TORDON K & as 1/2 lb/gal combination with 2 lb/gal2,4-D, TORDON 101, Dow Chem.	Sold as 3 lb/gal as triethanol amine salt, GARLON 3A, Dow Chemical Co.	Sold as 4 lb/gal butoxyethyl ester GARLON 4, Dow Chemical Co.
Herbicidal Use: target species	Controls broadleafed perennial weeds, vines & brush, particularly Maple.	Perennial vines & brush, particularly Ash.	Same as amine, but results appear more quickly.
preemergent rate	2-4 lb/a for deep-rooted broadleaf weeds.	Not recommended.	Not recommended.
postemergent rate	1-3 lb. for perennial broadleaf weed, 2-8 lb. for brush.	0.25-9 lb/a for broadleaf weeds & folair applied brush	Same as amine, but results appear more quickly.
Use Precautions: flammability, corrosiveness volatility, other.	TORDON 101 TOC flashpoint 46° C, noncorrosive, virtually nonvolatile, true solution, photodecomposable, hazardous to broadleaf crops, esp. tobacco.	GARLON 3A flash- 91° C, noncorrosive virtually non-volatile, true solution, photo-decomposable.	Same as amine, except 82°C, & volatile though less hazardous to many crops than 2,4-D ester.
Physiological behavior & mode of action:	Foliar & root entry, translocated to growing tissue, similar to 2,4-D.	Primarily foliar entry, translocated to growing tissue, similar to 2,4-D.	Same as amine. Results appear more quickly than amine.
Soil behavior, mobility & persistance:	Mobile in soil, persistent for months or years. Leachable.	Mobile in soil, halflife 46 days, biodegradable.	Same as amine.
Toxicology acute LD50	8200, Class 5, almost nontoxic.	713, Class 4, slightly toxic.	713, Class 4, slightly toxic.
Dermal Class, other.	Midly irritating Class 3.	Product irritating to skin, Class 3.	Mildly irritating Class 4. Toxic to fish.
Other pertinent information:	Not registered for use in Florida.	Product solvents may be hazardous to eyes of user.	Product solvents toxic to trout at 0.74 ppm for 96 hours.

II. NONSELECTIVE HERBICIDES

GRASS CONTROL		CONTACT HERBICIDES	
dalapon	ammonium sulfamate	diquat	paraquat (not labeled for railroad use in USA).
Sold as combination of sodium & magnesium salts, 72.5% & 12%, DOWPON M, Dow Chemical Co.	Sold as soluble crystal 95% ammonium sulfate, AMMATE X-NI, Du Pont Chemical Co.	Sold as 2 lb/gal dibromide salt, DIQUAT 2, Ortho (Chevron) Chemical Co. & REGLONE, ICI America's Co.	Sold as 2 lb/gal dichloride salt, PARAQUAT, Ortho (Chevron) Chemical. GRAMOXONE, ICI America's Co.
Annual & perennial grass control often in combination with other products.	Useful for brush control adjacent to crops.	Broad spectrum contact herbicide, usually used in combination with longer lasting products.	Broad spectrum contact herbicide, usually used in combination with longer lasting products.
Not recommended.	Not recommended.	Not labeled for use.	Not recommended.
15-25 lb/a plus 1/2% surfactant during warm, moist periods.	60 lb/100 gal solution, plus .25% surfactant, sprayed to wet.	0.5 lb (1 qt.)/a on seedlings or annuals, higher on perennials.	0.5 lb (1 qt.)/a on seedlings or annuals, higher on perennials.
Nonflammable, slightly corrosive to metals, nonvolatile, hygroscopic, true solution.	Nonflammable corrosive to ferrous metals & brass, not to aluminum or stainless steel, nonvolatile, true solution.	Nonflammable, noncorrosive, nonvolatile, true solution, photodegradable.	Nonflammable, noncorrosive, nonvolatile, true solution.
Foliar & root entry, translocated to growing tissue.	Foliar entry, acts as contact to herbacious perennials & annuals, translocated in woody plants.	Kills only the leaf tissue it contacts, not translocated.	Kills only the leaf tissue it contacts, not translocated.
Mobile in soil, biodegrades in 20-40 days.	Mobile in soil, biodegrades in 6-8 weeks.	Inactivated by soil.	Inactivated in soil.
9300, Class 5, Almost nontoxic.	3900, Class 4, Slightly toxic.	230, Class 3, Moderately toxic.	150, Class 3, Moderately toxic.
Moderately irritating, Class 3	Nonirritating, Class 5.	Moderately irritating, Class 3.	Mildly irritating, Class 4.
Easily washed off off plants, do not spray before rain.		Active over a wide range of temperatures. Gives brown out appearance.	Gives quicker brown out appearance than diquat. DO NOT INHALE Keep off skin & eyes. Fatal if swallowed!

II. NONSELECTIVE HERBICIDES

	CONTACT HERBICIDES (CONTINUED)		RESIDUAL HERBICIDES
Common (or Chemical) Name:	monosodium methane arsonate, MSMA	sodium chlorate	bromacil
Products & formulations available.	Sold at several lb/gal concentrations, example TRANSVERT, Union Carbide, MSMAMATE, Crystal Chemical Co.	Sold as 90% salt with fire retardant such as sodium metaborate. Sold as custom solutions, granulars & pellets.	Sold as 80% wettable powder, HYVAR-X Du Pont Chemical, or 2 lb/gal HYVAR XL, Du Pont, & as various granular concentrations.
Herbicidal use: target species	Broad spectrum contact herbicide, often used in combination with longer lasting products.	Broad spectrum contact dessicant often combined with longer lasting products	Long lasting control of deeprooted grass & broadleaf forbs.
preemergent rate	Not labeled for use.	Not recommended	2-5 lb/a for seedlings to 20 lb/a for pre & postemergent perennial control.
postemergent rate	4-6.6 lb/a plus 4% surfactant.	100-200 lbs/a alone or in combination with other herbicides.	
Use Precautions: flammability, corrosiveness, volatility, other.	Nonflammable, mildly corrosive, nonvolatile, do not use below 75°F. or without surfactant, true solution.	Flammable with organic material, corrosive to equipment, nonvolatile Must be used with proper fire retardant, very soluble.	Liquid formulation combustable & corrosive to aluminum, nonvolatile, slightly soluble in water, 815 ppm.
Physiological behavior & mode of action:	Foliar contact kills only the tissue it touches, not translocated.	Foliar dessicant, inhibits photosynthesis, not translocated.	Primarily root entry, inhibits photosynthesis. Some contact activity with surfactant.
Soil behavior, mobility & persistence:	Almost completely inactivated by surface adsorption & ion exchange.	Not available	Mobile in soil, biodegradable half-life 5-6 months.
Toxicology: acute LD50	700, Class 4 slightly toxic.	5000, Class 4 slightly toxic.	5200, Class 5, almost nontoxic.
Dermal Class, other.	Mildly irritating, Class 4	Mildly irritating, Class 4, irritates nasal septum.	Mildly irritating, Class 4
Other pertinent information:	Skin irritation of various products depends on their acidity or alkalinity.	Do not burn discarded bags.	Often used in combination with other herbicides, requires tank agitation.

II. NONSELECTIVE HERBICIDES

RESIDUAL HERBICIDES (CONTINUED)

atrazine	simazine	diuron	karbutilate
Sold as 85.5% water dispersible granule. ATRATOL 90, Ciba-Geigy. Also available as 80% WP by Shell & others.	Sold as 90% water dispersible granule PRINCEP 90, Ciba-Geigy also available as 80% WP by other manufacturers.	Sold as 80% wettable powder, KARMEX, Du Pont Chemical or as granular various % for dry application by several formulators.	Sold as 27% WP combination with 54% simazine, TANZENE 80W, Ciba-Geigy.
Pre or early postemergent control of many annuals & some perennial weeds.	Preemergent control of many annual & perennial broadleaf weeds & grasses.	Preemergent control of many perennial & most shallow rooted annual weeds.	Preemergent control of annual & expecially deep rooted perenial broadleaf weeds & vines
5-11 lb for annual, 11-22 lb. for perennial control, 22-44 lb/a for other problem weeds.	Similar to atrazine, nonselective rates begin at 4 lb per acre.	4-16 lb/a for control of seedlings & most annuals. Heavier rates for perennials.	2-4 lb/a a.i. for annuals 4-8 lb/a for perennial weeds. Higher rates will control brush.
Nonflammable, noncorrosive, nonvolatile, very slightly soluble, 33 ppm.	Nonflammable, noncorrosive, nonvolatile, nearly insoluble, 3.5 ppm.	Nonflammable, noncorrosive, nonvolatile, slightly soluble, 42 ppm.	Nonflammable, noncorrosive, nonvolatile, slightly soluble, 325 ppm.
Root entry, photosynthetic inhibitor. Requires rainfall to activate.	Root entry, photosynthetic inhibitor. Requires rainfall to activate.	Root entry, photosynthetic inhibitor. Requires rainfall to activate.	Root entry, photosynthetic inhibitor. Requires rainfall to activate.
Leaches moderately likely to biodegrade within 1 year.	Retained in upper 2 inches, persistence greater than that of atrazine.	Retained in upper inches, bio-and photo-degradable persistence greater than 1 year.	Leaches moderately.
5100, Class 5 almost nontoxic	5000, Class 5 almost nontoxic	3400, Class 4 slightly toxic	3000, Class 4 slightly toxic
Nonirritating Class 5	Nonirritating Class 5	Mildly irritating Class 4	Nonirritating Class 5
Will not control spilled corn. Requires tank agitation.	May remain adsorped during dry periods. Requires tank agitation.	Keep out of eyes. Requires tank agitation.	Tanzene maximum labeled rate 15 lb/a. Requires tank agitation.

II. NONSELECTIVE HERBICIDES

RESIDUAL HERBICIDES (CONTINUED)

Common (or Chemical Name:	hexazinone	tebuthiuron	sulfometuron methyl
Products and formulations available:	Sold as 90% soluble powder, VELPAR, Du Pont Chem., 2 lb/gal miscible liquid, VELPAR-L, 10% granular available by several formulators.	Sold as 80% wettable powder, SPIKE 80W, Elanco & various % granuler & pelletized formulations.	Sold as 75% dispersible granule for mixture with water, OUST, Du Pont Chemical Co.
Herbicidal use: target species	Broad spectrum preemergent control of many perennial grass & broadleaf weeds & brush.	Broad spectrum preemergent control of many perennial grass & broadleaf weeds & brush.	Selective pre- & post-emergent control of hard-to-kill perennial weeds, used in combination.
preemergent rate postemergent rate	6-12 lb/a for season long control or lesser rates in combination with other herbicides, 2-5 lb/a for contact & short term control.	1.2-2.4 a.i.lb/a for maintenance control 4-6 lb/a for virgin areas, 6 lb/a + for brush & resistant perennials. Postemergent not recommended.	1.2 oz/a for selective weeding, 2-6 oz/a. for nonselective, 6-12 oz/a on resistent perennials.
Use precautions: flammability, corrosiveness, volatility, other.	Nonflammable, noncorrosive, nonvolatile, solubility, 32,000 ppm, temperature sensitive.	Nonflammable, noncorrosive, nonvolatile, somewhat soluble, 2500 ppm	Nonflammable, noncorrosive, nonvolatile, slightly soluble, 70 ppm, hydrolyzed slowly in water.
Physiological behavior & mode of action:	Root & foliar entry, translocated, inhibits photosynthesis.	Root entry, translocated inhibits photosynthesis, causes death by depletion of root reserves.	Root & foliar entry, translocated inhibits cell division & plant growth, purplish necrosis.
Soil behavior, mobility & persistence.	Photo & biodegradable half life of 4 to 5 months, mobile in soil.	Leaches slowly to 12 in., half life 12-15 months, little lateral movement.	Subject to lateral movement on soil surface during rainfall. Half-life a few weeks.
Toxicology: acute LD50	1690, Class 4 slightly toxic.	644, Class 4 slightly toxic.	5000, Class 5 almost nontoxic.
Dermal Class, other.	Mildly irritating, Class 4	Nonirritating, Class 5	Mildly irritating, Class 4
Other pertinent information:	Warning! May irritate nose, throat, eyes & lungs. Requires tank agitation.	Needs rainfall to activate and tank agitation.	Do not store in suspension more than 2 days. Needs tank agitation.

II. NONSELECTIVE HERBICIDES

TRANSLOCATED HERBICIDES

chlorsulfuron	glyphosate	imazapyr
Sold as 75% dispersible granule for water mixture, TELAR, Du Pont Chemical.	Sold as 4 lb. glyphosate (3 lb. glyphosine) per gal including surfactant ROUNDUP, Monsanto Co.	Sold as 2 lb/gal acid equivalent, ARSENAL, American Cyanamid.
Wheat herbicide labeled for special problem annuals & perennials.	Very broad spectrum of most perennials & many brush species.	Broad spectrum, long term control of most annual & perennial weeds.
Not recommended.	Not recommended.	Not recommended.
1/4-1 oz/a for selective, to 3 oz. nonselective control.	1-5 pts/a on weeds higher on brush. 2% solution spray to wet.	2-6 pts/a on herbacious weeds & woody brush.
Nonflammable, noncorrosive, nonvolatile, slightly soluble (125 ppm) photolyzes in acid solution.	Nonflammable, but corrosive to ferrous metals (not stainless steel). Nonvolatile true solution.	Nonflammable, corrosive to mild steel, nonvolatile true solution.
Foliar entry, translocated, inhibits cell division, purple necrosis.	Foliar entry, translocated, defoliation occurs slowly. Amino acid inhibition.	Primarily foliar entry, translocated. Foliage dies slowly from buds to roots. Amino acid inhibition.
Not currently available.	Strongly absorbed, not mobile, half life less than 60 days.	Not currently available.
5545, Class 5 Almost nontoxic	5400, Class 5 Almost nontoxic	>5000, Class 5 Almost nontoxic
Mildly irritating, Class 4	Nonirritating, Class 5	Mildly irritating, Class 4
Recommended in combination with other herbicides.	Usuable alone or in combination with other herbicides.	Currently recommended used alone.

New Part 10, Geosynthetics, covers geotextile (engineering fabric) specifications for roadbed track stabilization applications. Geotextile fabric's use under railway track is dependent upon traffic, environmental and/or sub-grade conditions. Physical properties of regular, heavy and extra heavy weight geotextiles are indexed by methods of text. Also installation and maintenance methods are recommended. Mentioned as being required, is a minimum of 8 inch cover and a preferred depth of 12 inch cover between the bottom of tie and the geotextile fabric tamping.

Part 10
Geosynthetics

10.1 GEOTEXTILE (ENGINEERING FABRIC) SPECIFICATIONS FOR RAILROAD TRACK STABILIZATION APPLICATIONS

10.1.1 Introduction

10.1.1.1 Application Uses:

The use of geotextile fabric under railway track is dependent upon traffic, environmental and/or subgrade conditions. Geotextile shall be used when necessary to provide for additional roadbed filtration, planar (lateral) permeability, strength and modulus improvement, and separation of subgrade and subballast or subballast and ballast. It may also be used in hard to drain areas and areas beyond the economic ability of railways to provide adequate drainage.

Geotextile and related products also have numerous civil engineering applications outside of the track application described herein. Examples of these are: embankment construction over weak soils, access road stabilization, retaining wall construction, erosion control and filtration for drains. Such applications shall be addressed in other sections of the manual.

10.1.1.2 Application Locations:

The geotextile shall be used beneath ballast and/or subballast for mainlines, secondary rail lines, high tónnage unit train lines, switches, crossings, bridge approaches, retarders, and etc. on both new track construction and existing track rehabilitation.

An engineering analysis of existing or proposed conditions, including subgrade classification using the "Unified Soil Classification", should determine if a geotextile is required. Table 10.1.2.1 should assist in determining the type and weight of geotextile to be used. Additional information regarding possible uses of geotextile will be found in other parts of this manual.

10.1.2 Material Requirements:

The geotextile shall be a nonwoven fabric or equivalent, including composites, consisting of long chain polymeric filaments, yarns, staple fibers or other structural components of polyester, polypropylene, etc. formed into a stable network.

The geotextile shall be inert to commonly encountered chemicals, hydrocarbons, and mildew. The geotextile shall be resistant to ultraviolet light, rot, insects, rodents and conform to the properties in the following tables entitled "Geotextile Classification" and "Geotextile Requirements". The geotextile shall be tinted or otherwise treated to prevent the occurrence of snowblindness of handling personnel. The geotextile shall be resistant to abrasion from the movement of adjacent roadbed materials and of ballast. In some fabrics, resin treatment may

Table 10.1.2.1
Geotextile Classification

	(1) Symbol	(2) Soil Group	(3) Field Identification	(4) Frost Heaving	(5) Drainage	(6) Value As Filter Layer
GRAVELS	GW	Well-graded GRAVELS and GRAVEL-SAND mixtures, trace to no silt or clay	Wide range in grain sizes, substantial amounts of all intermediate sizes, no dry strength	None to very slight	Excellent	Fair
GRAVELS	GP	Poorly-graded GRAVELS and GRAVEL-SAND mixtures, trace to no silt or clay	Predominantly one size, or a range of sizes with some missing, no dry strength	None to very slight	Excellent	Fair to poor
GRAVELS	GM	GRAVEL some SILT, GRAVEL-SAND-SILT mixtures	Fines with low or no plasticity, slight to no dry strength	Slight to medium	Fair to very poor	Very poor
GRAVELS	GC	GRAVEL some CLAY, GRAVEL-SAND-CLAY mixtures	Plastic fines, medium to high dry strength	Slight to medium	Poor to very poor	Not to be used
SANDS	SW	Well-graded SANDS and SAND-GRAVEL mixtures, trace to no silt or clay	Wide range in grain sizes, substantial amounts of all intermediate sizes, no dry strength	None to very slight	Excellent	Excellent
SANDS	SP	Poorly-graded SANDS and SAND-GRAVEL mixtures, trace to no silt or clay	Predominantly one size, or a range of sizes with some missing, no dry strength	None to very slight	Excellent	Fair to poor
SANDS	SM	SAND-SILT mixtures	Fines of low to no plasticity, slight to no dry strength	Slight to high	Fair to very poor	Very poor
SANDS	SC	SAND-CLAY mixtures	Plastic fines, medium to high dry strength	Slight to high	Very poor	Not to be used
SILTS & CLAYS OF LOW PLASTICITY	ML	SILTS, very fine SANDS, ROCK FLOUR	Fine grained, slight to no dry strength	Medium to very high	Fair to very poor	Not to be used
SILTS & CLAYS OF LOW PLASTICITY	CL	CLAYS of low to medium plasticity, CLAY-GRAVEL-SAND-SILT mixtures	Medium to high dry strength	Medium to high	Very poor	Not to be used
SILTS & CLAYS OF HIGH PLASTICITY	MH	SILTS, SILT-SAND mixtures of high plasticity	Slight to medium dry strength	Medium to very high	Poor to very poor	Not to be used
SILTS & CLAYS OF HIGH PLASTICITY	CH	CLAYS of high plasticity	Sticky when wet, high dry strength	Medium	Very poor	Not to be used
ORGANIC	OH	Organic SILTS or CLAYS	High smell, dark colour, mottled appearance, slight to high dry strength	Medium to high	Poor to very poor	Not to be used
ORGANIC	PT	MUSKEG, PEAT	Dark colour, spongy feel and fibrous texture	Slight to high	Poor	Not to be used

Adapted from ASTM Method D 2487T

COLUMN	NOTES
2	Soil types in capitals and underlined make up more than 50% of sample. Other soil types in capitals make up more than 10%
4	Tendency of soil to frost heave
5	Ability of soil to drain water by gravity. Drainage ability decreases with decreasing average grain size
6	Value of soil as filter backfill around subdrain pipes to prevent clogging with fines, and as filter layer to prevent migration of fines from below

	(1) Symbol	(7) Erosion On Exposed Slope	(8) Value As Subgrade	(9) Pumping Action	(10) Stability In Compacted Fills	(11) Compaction Characteristics	(12) Typical Duty Type Geotextile Fabric Use
GRAVELS	GW	None*	Excellent	None	Very good	Excellent; crawler-type tractor, rubber-tired roller, steel-wheeled roller	None Required
GRAVELS	GP	None*	Excellent	None	Reasonably good	Good; crawler-type tractor, rubber-tired roller, steel-wheeled roller	None Required
GRAVELS	GM	None to slight	Good	None	Reasonably good	Good with close moisture control; rubber-tired roller, sheepfoot roller	None Required
GRAVELS	GC	None to slight	Good	Slight	Fair	Excellent; rubber-tired roller, sheepfoot roller	None Required
SANDS	SW	Slight to high with decreasing gravel content	Excellent	None	Very good	Excellent; crawler-type tractor, rubber-tired roller	None Required
SANDS	SP	High	Good	None	Reasonably good with flat slopes	Good; crawler-type tractor, rubber-tired roller	None Required
SANDS	SM	High	Poor	None to slight	Fair	Good with close moisture control; rubber-tired roller, sheepfoot roller	Slight Regular
SANDS	SC	Slight	Poor	Slight	Fair	Excellent; rubber-tired roller, sheepfoot roller	Slight Regular
SILTS & CLAYS OF LOW PLASTICITY	ML	Very high	Poor	Slight to bad	Poor	Poor to good with close control of moisture; rubber-tired roller; sheepfoot roller	Yes Regular
SILTS & CLAYS OF LOW PLASTICITY	CL	None to slight	Bad	Bad	Reasonable	Fair to good; rubber-tired roller, sheepfoot roller	Yes Heavy
SILTS & CLAYS OF HIGH PLASTICITY	MH	None to slight	Bad	Very bad	Poor	Poor to very poor; sheepfoot roller	Yes Heavy
SILTS & CLAYS OF HIGH PLASTICITY	CH	None	Bad	Very bad	Fair with flat slopes	Fair to poor; sheepfoot roller	Yes Extra Heavy
ORGANIC	OH	Variable	Bad	Very bad	Not to be used	Poor to very poor	Yes Extra Heavy
ORGANIC	PT	Not applicable	Remove completely	Very bad	Not to be used	Compaction not possible	Yes Extra Heavy

COLUMN	NOTES
7	Ability of natural soil to resist erosion on an exposed slope. Soils marked * may be used to protect eroding slopes of other materials.
8	Value as stable subgrade for roadbed, when protected by suitable ballast and subballast material. Good soils may be used to protect poorer soils in subgrade.
9	Tendency of soil to pump up and foul ballast under traffic
10	Stability of soil against bulging and subsidence when used in a rolled fill. Cross check with Column (7) to forecast tendency to erode
11	Equipment listed will usually produce the required densities with a reasonable number of passes when moisture content and thickness of lift are properly controlled
12	Typical type Geotextile Fabric. Use is dependent upon existing or proposed subgrade design. Fabric will not improve soil classification. If additional strength is required, use enough stabilized material, granular base material, sub-ballast and ballast to properly span the weak subgrade soil.

increase abrasion resistance. The average roll minimum value (weakest principle direction) for strength properties of any roll tested from the manufacturing lot or lots or particular shipment shall be in excess of the average roll minimum value (weakest principle direction) stipulated.

Geotextile Requirements: Physical Properties

INDEX PROPERTIES FOR TYPICAL MINIMUM VALUES

Test Methods for Geotextiles	Regular Typical Weight* 10-12 Oz/Sq.Yd.	Heavy Typical Weight* 12-16 Oz/Sq.Yd.	Extra Heavy Typical Weight* 16-20 Oz/Sq.Yd.
Grab Tensile Stregth - ASTM D-1682 (lbs) (using 1" wide by 2" tall jaws at 12-inch/min. strain rate on 4" wide by 8"tall sample and 3" gage length between jaws)	175	225	350
Elongation at Failure - ASTM D-1682 (%) (using 1" wide by 2" tall jaws at 12-inch/min. strain rate on 4" wide by 8" tall sample and 3" gage length between jaws)	20	20	20
Mullen Burst Strength - ASTM D-3786 (psi)	400	450	620
Planar Water Flow/ Transmissivity** (Sq. Ft./min. x 10^{-3}) (Normal Stress of 3 psi)	2	4	6
Coefficient of Normal Permeability (K) (cm/sec) Proposed ASTM 61-001	.1	.1	.1
Permittivity (Sec.-1) Proposed ASTM 61-001	.30	.25	.20
Apparent Opening Size (U.S. Standard Sieve No.) CW-02215 U.S. Standard Sieve Number larger than (using 10-minute sieve time and 5% or less of the glass beads pass the fabric)	70	70	70
Trapezoid Tear Strength - ASTM D-1117 (lbs) (using 3" wide by 2" tall jaws at 12-inch/min. strain rate on 3" wide by 8" tall sample and 1" gage length between jaws on the sample marked with trapezoidal outline).	100	130	150
Puncture Strength - ASTM D-751 (modified) (lbs) (using 5/16" flat tip end)	110	150	185
Abrasion Resistance (No satisfactory test is available at this time; ASTM is currently working on a testing procedure.)	Not Available	Not Available	Not Available

* Fabric weight: The weights indicated for the classification of material are for information only. It is recommended that the selection of material be based on the specifications using these tables as minimum values. Material selection should not be limited by the weights shown, i.e., geotextiles may accomplish the same purposes with more or less weight.

** Reference: Koerner and Bove, "Inplane Hydraulic Properties of Geotextiles", <u>Geotechnical Testing Journal</u>, Vol. 6, No. 4, Dec. 1983, p. 190-195.

TABLE 10.1.2.2

10.1.3 Packing and Identification Requirements:

The geotextile shall be marked approximately every 10 feet stating manufacturer's name, style or classification and special instructions (e.g., THIS SIDE UP).

The geotextile shall be provided in rolls wrapped with protective covering. A tag or other method of identification shall be attached to each wrapped roll of fabric indicating the following:

1. Manufacturer's name and address.
2. Date of manufacture of fabric.
3. Manufacturer's order number.
4. Number or symbol of manufacturer's production run.
5. Customer order number.
6. Weight per sq. yd. of fabric.
7. Width of roll.
8. Length of roll.

Each roll of fabric shall be wrapped individually and the protective covering shall be adequate for long or short term storage.

10.1.4 Compliance, Inspection, and Sampling Requirements:

A competent laboratory must be maintained by the producer of the geotextile at the point of manufacture to insure quality control in accordance with ASTM testing procedures. That laboratory shall maintain records of its quality control results and provide, upon request of the specifying agent prior to shipment or at any reasonable time thereafter, a manufacturer's certificate. The certification shall be based on minimum average roll values and shall include:

a) Name of manufacturer.
b) Chemical composition.
c) Product description.
d) Statement of compliance to specification requirements.
e) Signature of legally authorized official attesting to the information required.
f) Purchaser.

It is recommended that a fabric segment be taken from every 20th roll or at an interval specified by the Engineer in the field and be tested at an independent competent laboratory to indicate compliance with these specifications.

10.1.5 Construction Details and Methods:

The geotextile fabric shall be installed in accordance with the plans, specifications or as directed.

The geotextile may be spliced by overlap, sealing or sewing. The minimum overlap distance in the transverse or longitudinal direction shall be 2 feet. Sealed or sewed seams will be allowed if the overlap in the transverse or longitudinal directions is a minimum of 6 inches and the sealed or sewed seam grab tensile strength is equal to the minimum value of the geotextile in the weakest principle direction. The contractor will be allowed to patch small rips or tears in the fabric when approved by the engineer.

Prior to geotextile placement the subgrade shall be prepared and shaped to the lines and grades as directed. Special attention shall be given to eliminate any sag pockets in the roadbed and to facilitate drainage away from the track centerline.

The geotextile shall be stretched taut (both longitudinally and transversely) before backfilling. Special care shall be taken to avoid damage to the geotextile. Geotextile should be covered the same day as applied, if possible. The geotextile shall be covered after application within a week to 10 days in order to minimize any strength loss which may occur in some geotextiles. The protective cover must not be removed from the fabric roll until the day it is to be installed.

It is required to have a minimum depth of 8" cover and a preferred depth of 12" cover between the bottom of tie and the geotextile fabric before tamping.

Tamping of ballast materials shall be by setting the tamper feet to a minimum depth and using the minimum pressure required to compact the ballast. Tamper operator shall continue to observe the effects of the tamper foot on the geotextile fabric to insure that holes are not being punched in the fabric. Where siding or double track exist, this observation should be on the side where the ballast is restrained by lateral pressure from the existing adjacent track ballast. When track liners with spuds are used, the holes punched into the fabric by the spud shall be patched by removal of the cover material and the hole spliced as stated above.

10.1.6 Measurement and Payment:

Geotextile shall be measured for payment by the square yard.

Geotextile shall be paid by the square yard shipped, unless otherwise prescribed by the purchase contract.

COMMITTEE 4—RAIL

Committee 4 has proposed several additions and alterations to Part 2 and the Miscellaneous Part of Chapter 4.

Part 2's revision to the specifications for steel rails includes the following proposed alterations:

- adopting a 285 BHN minimum for 115-lb. rail and over
- lessening the high tolerance providing a total of 0.055 tolerance in rail height requirements
- providing for superior wording and a better definition of stamping specifications and prohibiting stamping within two feet of the rail end
- adding a Section 8 to cover ultrasonic testing as a part of a rail mill's operation
- adding a specification to cover sidesweep which is somewhat similar to the vertical upsweep specification which we have had for some time
- adding a specification for twist covered by Article 14.9
- adding a Section S2 covering ultrasonic testing of rails in rail mills

(Note: changes to specifications are shown in italics)

Part 2

Specifications

Specifications for Steel Rails

1. Scope

1.1 These specifications cover steel tee rails for use in railway track.

1.2 Supplementary requirements Sl through S3 shall apply only when specified by the purchaser.

2. Manufacture

2.1 The steel shall be made by any of the following processes: open hearth, basic oxygen, or electric furnace.

2.2 The steel shall be cast by a continuous process, in hot topped ingots, or by other methods agreed by purchaser and manufacturer.

2.3 Sufficient discard shall be taken from ingots and blooms rolled from ingots to insure freedom from injurious segregation and pipe.

3. Chemical Composition

3.1 The chemical composition of the standard rail steel determined as prescribed in 3.3 shall be within the following limits:

	Chemical Analysis Weight Percent Nominal Weight lb/yd		Product Analysis Weight Percent Allowance Beyond Limits of Specified Chemical Analysis	
Element	90 to 114	115 & Over	Under Min.	Over Max.
Carbon	0.67-0.80	0.72-0.82	0.04	0.04
Manganese	0.70-1.00	0.80-1.10*	0.06	0.06
Phosphorus, Max.	0.035	0.035	—	0.008
Sulfur, Max.	0.037	0.037	—	0.008
Silicon	0.10-0.50	0.10-0.50	0.02	0.02**

*The upper manganese limit may be extended to 1.25% by the manufacturers to meet the hardness specifications. When the manganese exceeds 1.10% the residual alloy contents will be held to 0.25% max. Ni, 0.25% max. Cr, 0.10% Mo.

**Continuously cast tolerances shall be 0.05% over maximum limit for Silicon.

3.1.1 Finished material representing the heat may be product tested. The product analysis shall be within the limits for product analyses specified in the Table of 3.1.

3.2 The chemical composition of alloy high strength rail will be subject to agreement of the purchaser and manufacturer.

3.3 Separate analysis shall be made from test samples representing one of the first three and one of the last three ingots or continuously cast blooms preferably taken during pouring of the heat. Determination may be made chemically or spectrographically. Any portion of the heat meeting the chemical analysis requirements of 3.1 may be applied. Additionally, any material meeting the product analysis limits shown in 3.1 may be applied after testing such material.

3.4 Upon request by the purchaser, samples shall be furnished to verify the analysis as determined in 3.3.

3.5 The first analysis shall be recorded as the official heat analysis, but the purchaser shall have access to all chemical analysis determinations.

4. Hardness Properties

4.1 Rails shall be produced as specified by the purchaser within the following limits:

	Standard Rail		High Strength Rail
	90-114 lb./yd.	115 and over lb./yd.	
Brinell Hardness	248 min.	*285 min.*	321-388

4.2 A Brinell hardness test shall be performed on a rail or a piece of rail at least 6 inches long cut from a rail of each heat of steel and a report furnished to the purchaser.

4.2.1 The test shall be made on the side or top of the rail head, after decarburized material has been removed, to permit an accurate determination of hardness.

4.2.2 The test shall otherwise be conducted in accordance with the American Society of Testing and Materials (ASTM) Standard Method of Test for Brinell Hardness of Metallic Materials El0 latest version.

4.3 If any hardness test fails to meet the specifications, two additional checks shall be made, one on each side of the point first measured. If both checks meet the specified minimum hardness as ordered, the heat shall have met the hardness requirement. If either of the additional checks fail, two further rails in the heat shall be checked with each of these two rails meeting the minimum ordered for the heat to be accepted. If any one of these two checks fails, individual rails may be tested for acceptance.

4.4 If for heat treated rails a test fails to meet the requirements of 4.1, the rails may be retreated, at the option of the manufacturer, and such rails may be retested in accordance with 4.2 and 4.3

5. Section

5.1 The section of the rails shall conform to the design specified by the purchaser subject to the following tolerances on dimensions:

	Inches (Thousandths) Plus	Minus
5.1.1 height of rail (measured within 1 ft. from end)	*0.040*	0.015
5.1.2 width of rail head (measured within 1 ft. from end)	0.030	0.030
5.1.3 thickness of web	0.040	0.020
5.1.4 width of either flange	0.040	0.040
5.1.5 width of base	0.050	0.050

5.1.6 No variation will be allowed in dimensions affecting the fit of the joint bars, except that the fishing templet may stand out not to exceed 0.060″ laterally.

5.2 Verification of tolerances shall be made using appropriate gages, as agreed upon by purchaser and manufacturer.

6. Branding and Stamping

6.1 Branding shall be rolled in raised characters on the side of the web of each rail at a minimum of every 16 ft. in accordance with the following requirements:

6.1.1 The data and order of arrangement of the branding shall be as shown in the following typical brand, the design of letters and numerals to be optional with the manufacturer.

132 (Weight)	RE (Section)	CC (Mehtod of Hydrogen Elimination if indicated in Brand)	Manufacturer (Mill Brand)	1982 (Year Rolled)	III (Month Rolled)

6.2 The web of each rail shall be hot stamped at a minimum of every 16 ft. on the side opposite the brand, *and shall not occur within two feet of either end of rails of standard lengths,* and in accordance with the following requirements:

6.2.1 The data shall be shown in the following typical stamping. The height of the letters and numerals shall be 5/8″.

297165 (Heat Number)	ABCDEFGH (Rail Letter)	12 (Ingot Number) or (Strand & Bloom Number)	BC (Method of Hydrogen Elimination, if indicated in stamping)

6.2.2 The top rail from each ingot shall normally be hot stamped "A" and succeeding ones "B", "C", "D", "E", etc., consecutively.

6.2.2.1 The top rail from each hot topped ingot may be hot stamped "B" and succeeding ones "C", "D", "E", etc. consecutively, when agreed between purchaser and manufacturer.

6.2.3 Ingots shall be numbered in the order cast.

6.2.4 Rails from continuous cast blooms shall be identified by a designation for heat number, strand number, and bloom number.

(Note strand and bloom numbers may be joined or may be coded at the manufacturer's option).

The rail shall be identified by an alphabetical designation beginning with "P", and succeeding "R", "S", "T", etc., consecutively, or any other identification of the position of the rail within the cast, as agreed between the purchaser and manufacturer.

6.2.5 Stamping shall be legible and not injurious to the rail. The characters shall be of a uniform depth *not exceeding 1/16-inch* and approximately centered on the web.

6.2.6 High strength rail shall be identified in accordance with Section 16.1.

7. Hydrogen Elimination

7.1 The rail shall be free *from* shatter cracks.

7.2 The above shall be accomplished by at least one of the following processes:

Control Cooling of Rails (CC) (See Appendix 1)
Control Cooling of Blooms (BC)
Vacuum Treated (VT)
Such other processes as will meet the conditions of 7.1 (OP)

7.3 The mill brand or stamp shall identify the process used by the initials in parenthesis shown in Section 7.2.

8. Ultrasonic Testing

8.1 *Rails shall be ultrasonically tested for internal imperfections to the provisions of 8.3 through 8.9.*

8.2 *Full length of the rail shall be tested using ultrasonic testing equipment provided by the manufacturer, except if agreed to between purchaser and manufacturer, rails may be tested in accordance with Supplementary requirement S2.*

8.3 *The calibration test rail shall be a full section rail of the same section as that being tested. The test rail shall be long enough to allow calibration at the same rate of speed as the production rail.*

8.4 *The size, shape, location and orientation of calibration references to be placed in the test rail shall be agreed upon by the purchaser and manufacturer. At least one reference shall be put into the test rail to represent each search unit in the system.*

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

8.6 *In the event of a calibration failure all rails processed since the last successful calibration shall be retested.*

8.7 *The sensitivity level of the system using the test rail shall be adjusted to detect the calibration references of Section 8.4 when scanning the rail at production speed. Any indication equal to or greater than the references shall be cause for initial rejection. A record will be made of each suspect rail. This record shall be available to the purchaser's inspector.*

8.8 *The suspect rail may be retested using manual non-destructive testing techniques before final rejection. The testing criteria of the manual non-destructive retesting shall be agreed upon by the manufacturer and purchaser.*

8.9 *Rejected rails may be cut back to sound metal as indicated by the ultrasonic testing subject to the length restrictions in Section 12.*

9. Resistance to Impact

9.1 Rail produced by a continuous casting process is not subject to this requirement.

9.2 Resistance to impact shall be determined on a machine which conforms to the requirements of the AREA "Specifications For Drop Test Machine."

9.3 Test Specimens

9.3.1 Drop tests shall be made on test specimens of rail not less than 4 ft. and not more than 6 ft. in length.

9.3.2 The test specimens shall be cut from the top of the top rail from one of the first three, one of the middle three, and one of the last three ingots of each heat.

9.3.3 Temperature of the test specimens shall not exceed 100°F.

9.4 Test Procedure

9.4.1 The distance between supports shall be 3 ft. for sections under 106 lbs. For sections 106 to 140 lbs., it shall be 4 ft. For section over 140 lbs., it shall be 4 ft. 8 in.

9.4.2 The test specimens shall be placed head upwards on the supports and subjected to one blow from the tup falling free from the following heights for rails of the nominal weights indicated.

Weight per Yard Pound	Feet
90-100	19
101-120	20
121 & Over	22

9.5 Test Requirements

9.5.1 If all three specimens withstand the above drop test without breaking between the supports, all of the rails of the heat will be accepted subject to final inspection for surface, section, finish, and testing for internal imperfections.

9.5.2 If any specimen breaks in a location other than between the supports, or due to a defective test specimen or drop testing machine malfunction, the test shall be disregarded and a retest shall be taken from the top of the rail involved.

9.5.3 If one of the three specimens fails, subject to the requirements of 9.4.2, all of the top rails of the heat shall be rejected.

9.5.4 Specimens shall then be cut from the bottom end of the same top rails or the top end of the "B" rails of the same ingots and tested subject to 9.4.2. If any of these specimens fails, the "B" rails of the heat shall be rejected.

10. Interior Condition

10.1 For rails from ingots, a test piece representing the top end of the top rail of each ingot of each heat rolled, which has passed the drop test requirement of Section 9, shall be nicked and broken. If the fracture on any test specimen exhibits seams, laminations, cavities, evidence of injurious segregation, or interposed foreign matter, the heat number and ingot number shall be recorded and the top end and bolt holes of the finished rail, so recorded, shall be closely examined for those defects. If the finished rail is clear of the above defects when presented for inspection, it shall be accepted, subject to the requirements of 11. If the finished rail shows defects, it shall be broken or cut back through successive rails to sound metal and accepted as a short rail, subject to the requirements of 11 and 12.

10.2 Short rails produced under this procedure shall be excluded from consideration in the limitation of 12.2.

10.3 Paragraph 10.1 may be waived for ingot cast steel if purchaser and manufacturer agree to ultrasonic testing in accordance with S.2.1.

10.4 Rails rolled from continuously cast blooms shall be evaluated for interior soundness by macro-etching in a hot acid solution.

10.4.1 One full section transverse rail specimen representing each strand of each heat cast shall be prepared and etched in a hot acid solution in order to reveal the macrostructure.

10.4.2 If any specimen fails to meet the macro-etch rail standard for interior quality, as agreed upon by the purchaser and manufacturer, two further samples of rail representative of the same strand shall be obtained.

10.4.3 These retests shall be taken one from each side of the original sample at positions selected by the manufacturer and the material from between the two retest positions shall be rejected.

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

10.4.5 All rails represented by failed tests shall be rejected.

10.5 Rails produced by a continuous casting process are not subject to the requirements of 10.1 and 10.2 for ingot cast steel.

11. Surface Classification

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

12. Length

12.1 The standard length of rails shall be 39 ft. and/or 80 ft., when corrected to a temperature of 60°F. Other standard lengths may be specified by the purchaser.

12.2 Up to 15 percent of 80 ft. or 9 percent ot 39 ft. rail of the total tonnage accepted from each individual rolling will be accepted in shorter lengths as follows: 79′-78′-77′-75′-70′-65′-60′-38′-37′-36′-33′-30′-27′-25′.

12.3 A variation of plus or minus 7/16 in. on 39 ft. rails or plus or minus 7/8 in. on 80 ft. rails from the specified length will be permitted.

12.4 Standard short length variations other than those set forth in 12.2 and 12.3 may be established by agreement between the purchaser and manufacturer.

12.5 Lengths of rails shall be designated with proper color paint as set forth in Section 16.

13. Drilling

13.1 The purchaser's order shall specify the amount of right-hand drilled and left-hand drilled rails, drilled-both-end rails and undrilled (blank) rails desired. The right-hand or left-hand end of the rail is determined by facing the side of the rail on which the brand (raised characters) appears.

13.1.1 When right-hand and left-hand drilling is specified, at least the minimum quantity of each indicated by the purchaser will be supplied.

13.1.2 Disposition of short-rails which accrue from left-hand drilled, right-hand drilled, and undrilled (blank) rail production, and which are acceptable in accordance with 12.2 shall be established by agreement between the purchaser and the manufacturer.

13.2 Circular holes for joint bolts shall be drilled to conform to the drawings and dimensions furnished by the purchaser.

13.2.1 A variation of nothing under and 1/16 in. over in the size of the bolt holes will be permitted.

13.2.2 A variation of 1/32 in. in the location of the holes will be permitted.

13.3 Fins and burrs at the edge of bolt holes shall be eliminated. The drilling process shall be controlled so as not to mechanically or metallurgically damage the rail.

14. Workmanship

14.1 Rails shall be straightened cold in a press or roller machine to remove twists, waves and kinks until they meet the surface and line requirements specified, as determined by visual inspection.

14.2 When placed head up on a horizontal support, rails tnat have ends higher than the middle will be accepted, if they have a uniform upsweep, the maximum ordinate of which does not exceed 3/4″ in 39 ft. as illustrated in Fig. 1.

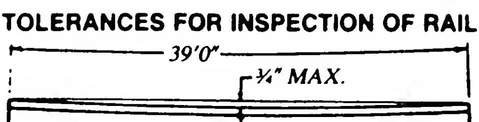


FIG. 1. Side Elevation of Rail Uniform Upsweep Tolerance per Section 14.2.

14.3 The uniform surface upsweep at the rail ends shall not exceed a maximum ordinate of 0.025″ in 3 ft. and the 0.025″ maximum ordinate shall not occur at a point closer than 18″ from the rail end as illustrated in Fig. 2.

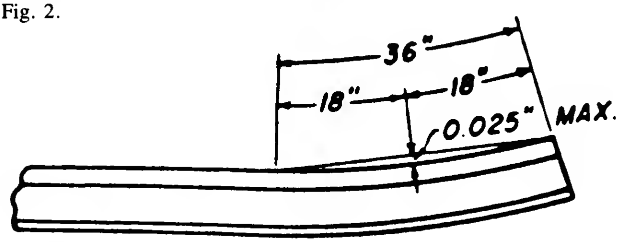


FIG. 2. Side Elevation of Rail Uniform Upsweep Tolerance at Rail Ends per Section 14.3

14.4 Surface downsweep and droop shall not be accepted.

14.5 Deviations of the lateral (horizontal) line in either direction at the rail ends shall not exceed a maximum mid-ordinate of 0.030-inches in 3 feet using a straight edge and of 0.023 inches at the end quarter point as illustrated in Figure 3.

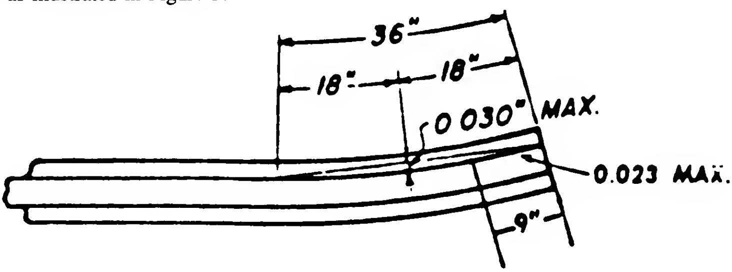


FIG. 3. Top View of Rail Lateral (Horizontal) Line Tolerance at Rail Ends per Section 14.5

14.6 *Uniform lateral sidesweep in any 39-feet shall not exceed 3/4 inch as illustrated in Figure 4.*

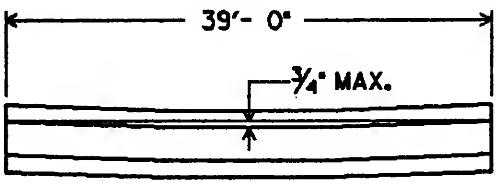


FIG. 4. Top View of Uniform Lateral Sidesweep Tolerance per Section 14.6

14.7 When required, proof of compliance with 14.2 shall be determined by string (wire) lining, and a straightedge and taper gauge shall be used to determine rail end surface and line characteristics specified in 14.3, 14.4, and 14.5.

14.8 Rails shall be hot sawed, cold sawed, milled, abrasive wheel cut, or ground to length, as specified by purchaser, on purchase order, with a variaton in end squareness of not more than 1/32 in. allowed. The method of end finishing rails shall be such that the rail end shall not be metallurgically or mechanically damaged.

14.9 *If the rail shows evidence of twist while being laid head up on the final inspection beds, it will be checked by inserting a taper or feeler gage between the base and the rail skid nearest the end. If the gap exceeds 0.090 in. the rail will be rejected or a twist gage may be used and if the rail exceeds 1.5° in 39 feet the rail will be rejected. Rejected rails may be restraightened.*

15. Acceptance

15.1 To be accepted, the rails offered must fulfill all the requirements of these specifications.

15.2 Only A-rails produced on the purchaser's order will be accepted.

15.3 Rails accepted shall be shipped and invoiced based on the calculated weight per yard for the rail section.

16. Markings

16.1 High-strength rails shall be marked by either a metal plate permanently attached to the neutral axis, hot stamped, or in the brand which gives the manufacturer, type and/or method of treatment. Heat treated rail shall be paint-marked orange and alloy rail shall be paint-marked aluminum.

16.2 "A" rails shall be paint-marked yellow.

16.3 Rails except for those 80 ft. or 39 ft. shall be paint-marked green.

16.4 Individual rails shall be paint-marked only one color, according to the order listed above, or as agreed upon by purchaser and manufacturer.

16.5 Paint markings will appear on the top of the head at one end only, at least 3 ft. from the end.

16.6 All short length rails produced shall have the length identified in a manner acceptable to the purchaser and manufacturer on the top of the head approximately one foot from each end.

17. Loading

17.1 All rails shall be handled carefully to avoid damage and shall be loaded with the branding on all rails facing the same direction. Rails of different markings shall not be intermixed in loading, but shall be segregated and loaded head up. If there are not enough rails of one marking for a full car, smaller groups consisting of tiers of different markings as approved by the purchaser, may be loaded onto one car.

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall apply only when specified by the purchaser in the inquiry, order, and contract.

S1. End Hardening

S1.1 The drilled ends may be specified to be end hardened. When so specified, end hardening and chamfering shall be in accordance with S1.1.1 through S1.1.7.

S1.1.1 End-hardened rails may be hot stamped with letters"CH" in the web of the rail ahead of the heat number.

S1.1.2 Water shall not be used as a quenching medium except in oil-water or polymer-water emulsion process approved by the purchaser.

S1.1.3 Longitudinal and transverse sections showing the typical distribution of the hardness pattern produced by any proposed process shall, upon request of purchaser, be submitted for approval before production on the contract is started.

S1.1.4 The heat-affected zone defined as the region in which the hardness is above that of the parent metal shall cover the full width of the rail head and extend longitudinally a minimum of 1-1/2 in. from the end of the rail. The effective hardness zone 1/2 in. from the end of the rail shall be at least 1/4 in. deep.

S1.1.5 The hardness measured at a spot on the centerline of the head 1/4 in. to 1/2 in. from the end of the rail shall show a Brinell hardness number range of 341 to 401 when decarburized surface has been removed. A report of hardness determination representing the product shall be given to the purchaser or his representative.

S1.1.6 The manufacturer reserves the right to retreat any rails which fail to meet the required Brinell hardness number range.

S1.1.7 Chamfering rail ends shall be done in such a manner as will avoid formation of grinding cracks.

S2. Ultrasonic Testing

S2.1 The rail may be specified to be ultrasonically tested for internal imperfections by the purchaser to the provisions of S2.2.

S2.2 Manual Ultrasonic Test of Web at the Rail Ends for Weld Plant Application.

S2.2.1 Manual End testing shall be performed using standard ultrasonic testing equipment acceptable to the purchaser and manufacturer.

S2.2.2 The search unit shall be a standard dual element crystal or similar transducer acceptable to the purchaser and manufacturer.

S2.2.3 The calibration test block shall be of the following characteristics: Material 4340 AISI Steel/Nickel plated, manufactured in accordance with ASTM E428. As an alternate, reference standards may be fabricated from a section of rail as agreed upon between the purchaser and manufacturer.

S2.2.4 Dimensions of the calibration test block and calibration references shall be agreed upon by the purchaser and manufacturer. (For calibration reference the recommended thickness of the block should approximate the thickness of the rail web and contain a 1/8" flat bottom hole drilled to one-half the thickness.)

S2.2.5 Calibration of the instrument shall be performed before the commencement of testing, every 100 rail ends thereafter, and after any test delay exceeding 30 minutes.

S2.2.6 When the search unit is coupled to the calibration test block, the indication height from the calibration reference shall serve as a reference level for the test. (Recommended reference levels should appear from 40% to 80% of the maximum height on the cathode ray tube graticule.)

S2.2.7 Couplant shall be distributed over the entire web area at least 12" from the end of the rail and the search unit moved over the entire area in vertical and/or horizontal sweeps.

S2.2.8 Any indication equal to or exceeding the reference level shall be cause for rejection.

S2.2.9 Rejected rails may be cut back to sound metal as indicated by the ultrasonic testing, subject to the length restrictions in Section 12.

APPENDIX 1

Inasmuch as the controlled cooling of rails has proved a successful method for the elimination of hydrogen, the following procedure is presented as one which will meet the requirements of Section 7.1.

1. All rails shall be cooled on the hot beds or runways until full transformation is accomplished and then charged immediately into the containers. In no case should the rail be charged at a temperature below 725°F.

2. The temperature of the rails before charging shall be determined at the head of the rail at least 12 in. from the end.

3. The cover shall be placed on the container immediately after completion of the charge and shall remain in place for at least 10 hours. After removal or raising of the lid of the container, no rail shall be removed until the temperature of the top layer of rails has fallen to 300°F or lower.

4. The temperature of an outside rail or between an outside rail and the adjacent rail in the bottom tier of the container, at a location not less than 12 in. nor more than 36 in. from the rail end, shall be recorded. This temperature shall be the control for judging rate of cooling.

5. The container shall be so protected and insulated that the control temperature shall not drop below 300°F in 7 hours for rails 100 lbs. per yd. in weight. or heavier from the time the bottom tier is placed in the container and 5 hours for rails of less than 100 lbs. per yd. in weight. If this cooling requirement is not met, the rails shall be considered control-cooled, provided that the temperature at a location not less than 12 in. from the end of a rail at approximately the center of the middle tier does not drop below 300°F in less than 15 hours.

6. The purchaser shall be furnished a complete record of the process for each container of rails.

Part 2's new section on frequency of rail testing gives some guidelines to the industry relating to the frequency of rail testing. Heretofore, AREA has not made any statement relating to minimum acceptable standards for frequency of rail testing. The minimum testing frequency is based on traffic density and rail processing.

Determining Minimum Detector Car Test Intervals

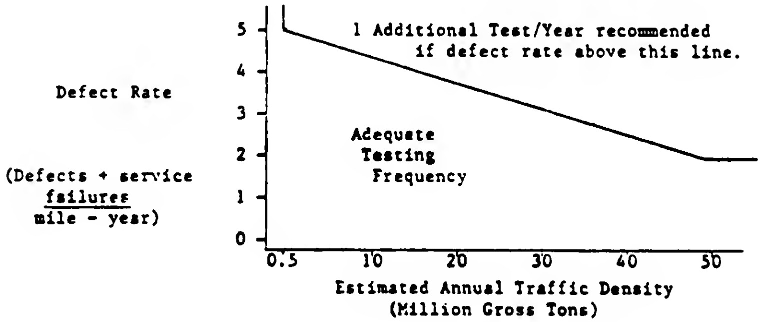
1. Use TABLE to find minimum testing frequency based on traffic density and rail processing.

2. Use CHART to determine if one additional testing run is needed based on defect rate.

Estimated Annual Traffic Density
(Million Gross Tons)

Rail Processing	Under 10 MGT*	10-20 MGT	20-40 MGT	Over 40 MGT
Control Cooled	1 Test/year	1 Test/year	1 Test/year	2 Tests/year
Non-Control Cooled	1 Test/year	1 Test/year	2 Tests/year	2 Tests/year

*Miscellaneous track carrying less than 0.5 MGT and/or speeds less than 10 MPH need not be tested.



These test intervals are presented as guidelines. Additional testing may be dictated by (1) a sudden increase in traffic density; or (2) increase in train speed or consist (unit train operation).

Part 2's revision on quenched angle bars and compromise bars updates the section on the quenched angle bars and compromise bars to cover more modern manufacturing methods. This section also accommodates the forged compromise bars which are currently quite popular throughout the industry. It recommends the depth of the decarburization layer of forged bars and the marking and stamping of bars to indicate the name or brand of the manufacture, the section designation, and the year of the manufacture. (Note: changes to specifications are shown in italics).

SPECIFICATIONS FOR QUENCHED CARBON-STEEL JOINT BARS AND FORGED COMPROMISE JOINT BARS

1. Scope

These specifications cover heat treated, carbon-steel joint bars *and forged compromise joint bars* for general use in standard railroad tracks.

2. Process

The steel shall be made by one or more of the following processes: open hearth, basic oxygen or electric furnace.

3. Discard

Sufficient discard shall be made from each ingot to insure freedom from piping and undue segregation.

4. Heating and Quenching

The bars shall be uniformly heated for punching, slotting, shaping, *forging* and subsequently quenched. *Maximum depth of decarburization layer of forged bars shall not exceed 0.040 inches.*

5. Chemical Composition

The steel shall conform to the following requirements as to chemical composition:

Carbon	0.35 percent to 0.60 percent
Manganese	Not over 1.20 percent
Phosphorus	Not over 0.04 percent

6. Ladle Analysis

An analysis of each heat of steel shall be made by the manufacturer to determine the percentages of carbon, manganese, phosphorus, and sulfur. This analysis shall be made from a test ingot taken during the pouring of the heat. The chemical composition thus determined shall be reported to the purchaser or his representative, and the percentages of carbon, manganese, and phosphorus shall conform to the requirements specified in Art. 5.

7. Check Analysis

An analysis may be made by the purchaser from a finished bar representing each heat. The percentages of carbon and manganese thus determined shall conform to the requirements specifed in Art. 5, and the phosphorus content shall not exceed that specified by more than 25 percent.

8. Tensile Properties

(a) The material shall conform to the following requirements as to tensile properties:

Tensile strength, min. psi	100,000
Yield point, min. psi	70,000
Elongation in 2 in., min. percent	12
Reduction of area, min. percent	25

(b) The yield point shall be determined by the drop of the beam or halt in the gage of the testing machine operated at a cross-head speed not to exceed 1/8 in. per min. The tensile strength shall be determined at a speed of head not to exceed 1 1/2 in. per min.

9. Bending Properties

(a) Bend Test

The bend test specimen specified in Art. 10 shall stand being bent cold through 90 deg. without cracking on the outside of the bent portion around a pin the diameter of which is not greater than three times the thickness of the specimen.

(b) Optional Bend Test

If preferred by the manufacturer and approved by the purchaser, the following bend test may be substituted for that described in paragraph (a): A piece of the finished bar shall stand being bent cold through 45 deg. without cracking on the outside of the bent portion around a pin the diameter of which is not greater than three times the greatest thickness of the section.

10. Test Specimens

Tension and bend test specimens shall be taken from the middle of the head at the center of the finished bars. Tension test specimens shall be machined to the form and dimensions shown in Fig. 1. Bend test specimens may be 1/2 in. square in section or rectangular in section with two parallel faces as rolled and with corners rounded to a radius not over 1/16 in.

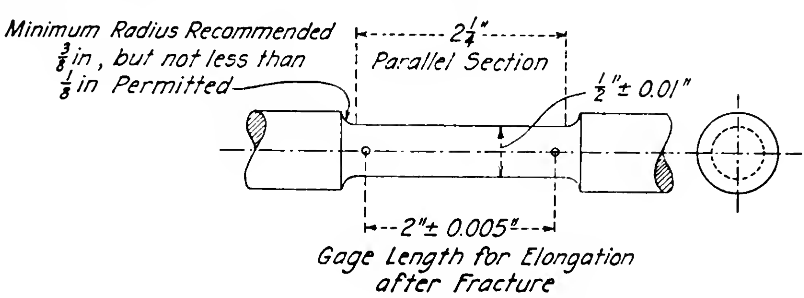


FIG. 1—Standard round tension test specimen with 2-in. gage length.

Note-The gage length, parallel section, and fillets shall be as shown, but the ends may be of any shape to fit the holders of the testing machine in such a way that the load shall be axial.

11. Number of Tests

(a) One tension test and one bend test shall be made from each lot of 1,000 bars or fraction thereof, but not less than one test for each heat on each day on which bars are heated and quenched.

(b) If any test specimen shows defective machining or develops flaws it may be discarded and another specimen substituted.

(c) If the percentage of elongation of any tension test specimen is less than specified in Art. 8 and any part of the fracture is more than 3/4 in. from the center of the gage length, as indicated by scribe scratches marked on the specimen before testing, a retest *of additional specimen* shall be allowed *as per Section 12.*

12. Retests

If the results of the mechanical tests of any test lot do not conform to the requirements specified, the manufacturer may retreat such lot not more than twice, in which case two additional tension tests and two additional bend tests shall be made from such lot, all of which shall conform to the requirements specified.

13. Workmanship

The bars shall be smoothly rolled, or *forged,* true to template and shall accurately fit the rails for which they are intended *and shall provide a true alignment of the gage and running surfaces of the two rails being connected. (Head easement is recommended per Figure 8 of this chapter.)* The bars shall be either sheared or sawed to length, and the punching and slotting shall conform to the dimensions specified by the purchaser. A variation of plus or minus 1/32 in. from the specified size of holes, or plus or minus 1/16 in. from the specified location of holes, and of plus or minus 1/8 in. from the specified length of joint bar will be permitted. Any variation from a straight line in a vertical plane shall be such as will make the bars high in the center. The camber in either plane shall not exceed 1/32 in. in 24-in. bars and 1/16 in. in 36-in bars.

14. Finish

The material shall be free from injurious defects and shall have a workmanlike finish.

15. Marking and Stamping

The name or brand of the manufacturer, the section designation, and the year of the manufacture shall be *either hot stamped on the side of each of the bars or rolled in raised letters and figures on the side of each of the bars.* A serial number representing the heat shall be hot stamped on the outside of the web of each bar, near one end. *Each compromise joint bar shall also have the rail sections shown at each end along with the word "Gage" or "Out" to indicate on which side of the rail bar is to be used. (If the compromise joint bars are interchageable, the words gage and out will be omitted.)*

16. Inspection

The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

17. Rejection

(a) Unless otherwise specified, any rejection based on tests made in accordance with Art. 7 shall be reported to the manufacturer within five working days from the receipt of samples by the purchaser.

(b) Material that shown injurious defects subsequent to its acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

18. Rehearing

Samples tested in accordance with Art. 7 that represent rejected material shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may request a rehearing within that time.

Part 2's revision on pressure butt weld failures gives the industry an opportunity to view the success of our flash butt welding in this country with its acceptably small failure rate. For rail sections cut-in with joint bars flame-cut ends should be saw-cut a distance of at least 2 inches to remove the torch-cut end. Likewise, for rail sections cut-in and thermite welded, the torch-cut ends need not be saw-cut off provided that the weld is made in accordance with recommended practice "Thermite Welding-Rail Joints" revised 1980, (page 4-2-6.7. 1981)."

Revision of "Recommended Field Repairs To Pressure Butt Weld Failures", Page 4-2-6.10, AREA Manual For Railway Engineering.

Part 1. Repair by cutting in a short section of rail with the application of standard joint bars:

Present Paragraph (d)-Saw cut the CWR, or flame cut if approved, on each side of the failed weld to obtain an opening for a short section of rail. It is recommended that the short rail be one-half the standard rail length to 36 ft. long or at least 3 ft. shorter than the standard length. If *flame cut, the cut should be reasonably smooth. Smooth by polish grinding if necessary.*

Proposed Revision Paragraph (d)

- - - or at least 3 ft. shorter than the standard length. *If flame cut, the ends shall be saw cut to remove the torch cut end for a distance of at least two inches.*

Part 2. Repair by cutting in a short section of rail and thermite welding the rail ends:

Present Paragraph (a) -Proceed as outlined in paragraphs (a) through (e) above, except it is recommended that the short rail be at least 10 ft. long or longer, preferably one-half the standard rail length.

Proposed Revision Paragraph (a)

- - - *preferably one half the standard rail length and the torch cut ends need not be saw cut off provided that the weld is made in accordance with recommended practice "Thermite Welding-Rail Joints," Revised 1980, (Page 4-2-6.7, 1981).*

Part 2's new section on magnetic particle inspection gives the industry some feel for the manner in which magnetic particle testing should be performed in welding plants. Heretofore, the AREA had not furnished any information relating to this practice. Magnetic particle inspection techniques provide indications of flaws or injurious defects in welds. To aid inspectors in evaluating the quality of rail welds, inspection procedures are specified. In general, a true flaw or defect in a weld will be revealed as a well defined straight line by magnetic particle inspection.

MAGNETIC PARTICLE INSPECTION PROCEDURE GUIDELINES

Magnetic particle inspection techniques, when applied to rail weldments, quite often reveal indications that may or may not be the result of the presence of flaws or injurious defects in the weld.

To aid the magnetic particle inspectors in evaluating the quality of rail welds, the following inspection procedures are suggested:

1. All butt line indications are to be cut out. (The amount of rail to be cut out and the means of making the cut are purposely omitted here, since this is intended only as an inspection guideline.)
2. Indications showing off the butt line (light and fuzzy), should be passed as acceptable, and a notation made on the inspection record.
3. Sharp indications outside the butt line, up to 1/8" in length, should be passed as acceptable, and a notation made on the inspection record.
4. Sharp indications outside the butt line, over 1/8" in length, should be cut out and rewelded once. If a similar indication recurs after re-welding, the disposition of the weld will be made by the welding plant supervisor.

As a further aid in evaluating questionable indications showing up in the weld area, as revealed by magnetic particle inspection, one or more of the following procedures may be of assistance:

1. Wipe the powder off the indication with a dry rag, and recheck with *residual* magnetism only (no power applied to the field).

   a. If it is a true defect, the powder will gather again, although lighter than before. The weld should then be cut out and rewelded.

   b. If it is a noninjurious condition, the powder will *not* gather again. Such welds should be passed as acceptable and a notation made on the inspection record.

2. Refinish the questionable area with emery cloth or grinder.

   a. Recheck with normal magnetic field.

   b. Check further with residual magnetism, as described in Item No. 1 above, if necessary.

3. A 5-power magnifying glass may be of assistance in examining questionable indications.

In general, a true flaw or defect in a weld will be revealed as a well defined straight line by magnetic particle inspection; whereas, a noninjurious condition will usually appear to be relatively indistinct, will parallel the flow lines in the weld, and may be slightly curved.

Miscellaneous Part's revision to the purchase of rail section (page 4-M-2) recommends that we delete the 106 lb. rail and add, the 133 lb. rail section. The 106 lb. rail is not being utilized to any great extent in this country and was produced only by one mill. The mill involved does not object to the deletion of this particular section. The addition of the 133 lb. rail, is due to the rather large quantities of this product which are utilized in this country and should become a part of the specification.

Committee 5 - Track

Committee 5 has recommended the addition of a section on the use of abrasive wheels to the Miscellaneous Part of Chapter 5. Many railroads presently have directives to their maintenance-of-way welders covering the storage, handling, transporting and operating of grinding wheels used for frog, switch and rail-end welding. The recommended practice incorporates these items and the safety aspects involved with the use of grinding wheels. It is very comprehensive, going into details of inspecting, mounting and operating the wheels, while still sufficiently general that it covers all types of wheels used in the track work.

Recommended Practice for Use of Abrasive Wheels

1. Scope:

   It is recommended that the current issue of the American National Standard for safety requirements for use, care, and protection of abrasive wheels, sponsored by the International Association of Governmental Labor Officials, Grinding Wheel Institute and associated organizations be followed. Issues may be obtained from A.N.S.I., 1430 Broadway, N.Y., N.Y. 10018.

2. General Safety

   A. Every precaution should be taken to prevent fire caused by sparks from grinding wheels and to check area thoroughly for any smoldering fire before leaving.

B. It is recommended that each wheel be speed tested at at least the maximum test speed, in accordance with B7.1 Section 7 of the A.N.S.I. standards, and documented with a letter from the manufacturer. Manufacturers must maintain records to substantiate the tests and warranty of same is to be indicated on product labels.
Always compare the operating speed recommended for the wheel against the machine operating speed. Never operate a wheel over its maximum operating speed. Excessive RPM could result in disintegration of the wheel. The maximum operating speed in RPM will be shown by the manufacturer on the label of each wheel. Before applying a grinding wheel the operator must check to determine that the maximum RPM shown on the wheel will not be exceeded. The RPM of the grinding machine must be checked by using a tachometer (speed counter). When the machine RPM is in excess of that shown as the maximum allowable for the particular wheel to be used, the governor must be adjusted to provide the proper RPM's. In no case will the operator take over the speed control of the grinding machine engine by hand operation to accelerate it with a grinding wheel and appurtenances on the spindle.

C. When a new wheel is being started, allow it to operate for about one minute before being applied to a working surface.

D. Only the grinding machine operator or helper should stand near an operating grinder, and these people should avoid standing in line with the grinding wheel, except when necessary to perform their work. (Refer to Section 5 Paragraph B.)

E. Always use safety glasses with side shields or safety goggles while operating grinding machine.

F. Never use a wheel that has been dropped.

G. An inspection should be made for damage to the guard, flanges, or nuts, and to ensure that the spindle has not been sprung out of balance or bent in the event of breakage of a grinding wheel. Machines should be inspected each day by the operator to see that the arbors, adaptors or other parts are free from wear. (Refer to Section A - Grinding Wheel Mounting).

H. Shut down the grinding machine while moving it from one location to another. Avoid any possible damage to the grinding wheel.

I. Periodic inspections should be made for defects in grinding wheels in use and for irregularities in the grinding machine, such as unusual vibrations or shaking, worn shaft or any unusual increase in engine speed. Wheels showing any visible evidence of cracks or damage should be destroyed.

J. Any damaged or unsafe grinding wheels must be destroyed to prevent accidental usage.

K. Wherever possible, reinforced wheel should be used.

3. Storage

A. Grinding wheels must be handled and stored with care. Extreme temperatures will affect the structural integrity of the wheel. Extremes of humidity and moisture can disrupt the balance of a wheel, causing it to fly apart while in use.

B. Grinding wheels are extremely fragile in some circumstances, and need special treatment. Wheels should not be dropped or struck, and tools or other material must not be placed on top of grinding wheels.

C. Grinding wheels should be stored in their shipping boxes laying flat on a flat surface until used, and must be stored in a dry place. Weight of shipping boxes and contents, when feasible, should be limited to approximately 50 pounds.

D. Grinding wheels stored or being carried in trucks must not be exposed to water, solvents, oil, dampness or extreme temperatures. Suitable racks or bins should be provided to prevent damage.

E. Abrasive wheel should not be used after three (3) years from manufactured date. Date, including month and year, of manufacture to be indicated on all wheels.

4. Grinding Wheel Mounting (See ANSI B7.1, Sections 5 & 6.)

A. Grinding wheels must fit freely on the spindles and should not be forced on, nor should they be loose.

B. Blotting paper washers (compressible washers) must be fitted between the wheel and the flanges when not an integral part of the wheel.

C. Spindle nuts should only be tightened enough to hold the grinding wheel firmly, otherwise the clamping pressure may damage the grinding wheel. There must be no alterations to a grinding wheel to force it to fit. Use the proper wheel only.

D. Bearing surfaces on mounting flanges and washers must be clean and flat.

E. The soft metal bushings furnished with some grinding wheels should not extend beyond the wheel sides.

F. The washers or flange facings of compressible material which fit between the faces of the wheel and its flanges must always be known to be in place before the wheel is mounted.

G. Where wheels are mounted by means of a central spindle nut and flanges, the spindle should be of sufficient length and should be threaded to a sufficient length so that when the wheel and flanges are mounted there will be room for a full nut on the spindle. The threading should extend well inside the flange, or washers should be placed between the outer flange and the nut.

H. Threaded nuts, or the central spindle nut, must be threaded in a manner that will tighten the nut as the spindle or wheel rotates

I. Closely inspect all grinding wheels before mounting. Suspend the wheel between the thumb and forefinger and strike GENTLY with a wooden handle or similar object. If the wheel is clean of foreign matter and is not damaged or cracked, it will have a clear ring.

5. Operation (See ANSI B7.1 Section 7)

A. Operation of grinding machines shall not be at a speed higher than that recommended by the wheel manufacturer. The wheel must have this stamped on the side, and should not be used if this number is absent.

B. All grinding wheels should be run at full operating speed for at least one (1) minute before grinding. The first contact made with the wheel on the material to be ground should be light to allow the wheel to become heated so as to permit any defects in the wheel to indicate their presence. During this time the grinding machine operator must place himself to one side, out of range of any possible danger if the wheel should break.

C. Use of excess pressure on the wheel can be detrimental to weld quality. If the grinding speed slows markedly or the work surface gets hot and discolored, pressure must be reduced.

D. Drive engines, electric motors, or control air supply must not be started or turned on while a grinding wheel is in contact with any surface.

E. Never start or operate a grinding machine without the wheel hood or guard in place.

F. Grind only the material for which the machine is designed. Work should NEVER be jammed into the wheel.

G. Grinding on the rim of cup wheels should never be permitted. Wheels out of balance through wear must be removed from the machine and discarded.

H. When grinding is completed, the operator must shut down the grinding machine before leaving the equipment.

I. When a grinding wheel breaks, an inspection must be made to assure that the guard and flanges have not been damaged. A full investigation and report of each broken wheel should be made, and in the event of an injury, machine shall be taken out of service pending full investigation.

J. Proper guards must be used to limit extent of damage and injury in the event of wheel failure. (See ANSI B7.1 Section 4.)

K. Some of the causes of wheel breakage on grinding machines are improper mounting of the wheel, worn or distorted flange plates, improper speeds, abusive operation, careless handling and oil or moisture soaked wheels.

6. Grinding Practice

General

A. Prescribed types of grinding machines should be used for designated kinds of work. Machines must be sufficiently rigid and substantial to minimize vibration and its adverse effect on the grinding wheel.

B. Only persons who have been properly qualified should perform grinding work.

C. All welded areas must be finish ground immediately after welding is completed.

D. All grinding heads must be equipped with a protection hood or wheel guard.

E. The removable outside portion of guard for the straight hand pieces used with all flexible shaft grinders must be in place when the hand piece is in use.

F. The band type guard used with cup type grinding wheels must be positioned so that at no time will the wheel protrude beyond the edge of the guard a greater distance than indicated in the following table:

Overall thickness of grinding wheel in inches	Maximum exposure of wheel beyond edge of guard in inches
1"	1/2"
2"	3/4"
3"	1"
4"	1½"

7. Grinding Equipment

A. For surface grinding on rail ends, engine burns and thermite butt welds, grinders equipped with mechanical vertical feed control are recommended. Except in an emergency, surface grinding should not be done with a hand held grinder.

B. For cross grinding to remove overflow from rail ends or providing clearance between rail ends to avoid chipping, a cross-cut grinder with a one-eighth (1/8) inch reinforced wheel or flexible shaft grinder with a cross cutting attachment and one-eighth (1/8) inch wheel are recommended.

C. For grinding frogs, track crossings, switch points and stock rails, hand-held grinders or flexible shaft attachments may be used. Grinding machines with mechanically fed wheels may be used on frogs, track crossings and stock rails. Recommend reinforced wheels be used wherever possible.

8. Grinding rail end surface welds

A. The higher rail end should first be ground to a straight surface as determined by holding an eighteen

(18) inch straight edge even with the end of the rail. Grinding should not extend beyond the limits of the weld except to make a smooth transition between welded and adjacent rail surfaces. The undamaged adjacent surface of the rail should not be lowered.

9. Grinding welded engine burns and thermite butt welds
   - A. The welded engine burns and thermite butt welds must be ground to conform to the contour of the existing rail head. Grinding should not extend beyond the limits of the weld except to make a smooth transition between welded and adjacent rail surfaces.
   - B. Grinding must be completed while the weld is hot..
10. Cross grinding rail ends
    - A. On joints where the expansion is one-sixteenth (1/16) inch or greater, the one-eighth (1/8)inch reinforced wheel must be used to grind out all excess or flowed metal in the expansion area.
    - B. On joints where the expansion is one-sixteenth (1/16) inch or less, referred to as tight joints, the one-eighth (1/8) inch reinforced wheel must be used and the grinding made to a depth of three-sixteenths (3/16) inch.
    - C. The grinding wheel must not come into contact with the splice bars or rail head bond wire.
11. Grinding frogs, track crossing and switch points
    - A. Grinding should be used for the following purpose:
      1. Preventative grinding: The removal of overflowed metal from flangeways on new track material in order to extend the service life. The grinding may have to be done several times until work hardening has occurred.
      2. Preparation grinding: The removal of spalled, cracked, flowed and work hardened metal prior to welding (cutting torch shall not be used for this purpose.)

3. Finish grinding: The finish ground frog, track crossing and switch point should closely conform to original specifications to produce a smooth surface, proper flangeway and radius. Use gage to check flangeway clearance and radius.

12. Grinding stock rails

A. Grind all overflow off the gage side of the stock rail opposite the switch point contact area. The ground area must extend four (4) inches beyond each end of contact area.

13. Rail cutting

A. Abrasive wheels should be stored under cover, not in the same car or storage area where oil is stored, and should not be used when wet, fouled with foreign particles, overheated or glazed. They should be stored in a flat position when carried in trucks.

B. Injuries are likely to occur if the saw workhead is not oscillated and the abrasive blade gets overheated or warps while sawing a rail.

C. Any tie plate or rail anchor falling directly under the location of the cut should be removed.

D. Operators should ease the abrasive wheel onto the rail head and then maintain a constant pressure throughout the entire cut.

14. Hand-held Abrasive Rail Saws

Recommend that ANSI B7.5 safety code be adhered to in the use of these type saws.

A. Saws shall be firmly attached to the rail to provide safe control and proper alignment while cutting rail. The equipment shall not be used for any other purpose than cutting rail.

B. Safety Precautions (Refer to ANSI B7.5 Section 4)

To avoid overspeed, sufficient fuel must be in machine to prevent interruption of cutting.

Committee 6 - Buildings

Committee 6 has recommended the removal of Parts 5—Design criteria for trailer-on-flat-car or container-on-flat-car facilities, 7—Pre-engineered metal buildings, and 11—Portable prefabricated buildings from Chapter 6. Part 5 is outdated and falls under the purview of Committee 14, Yards and Terminals. Support buildings, necessary in a TOFC facility, can be designed from Chapter 6's Part 2, Railway office building criteria. Part 7 describes material and products which are not railroad specific and are more adequately detailed in other technical references. Part 11 likewise describes products and criteria that are available from non-railroad industry sources.

In 1983 a bibliography of past Committee 6 reports was printed as information in Bulletin 693 on pages 412-415. This listing provides a valuable reference of information and should, Committee 6 recommends, be incorporated as a new Part 17 of Chapter 6. It would be updated periodically.

Committee 8 - Concrete Structures and Foundations

Committee 8 has recommended minor revisions to Part 23 - Pier protection systems at spans over navigable streams, of Chapter 8. Part 23 became a part of the Manual in 1980, and since then several items have become necessary to clarify and update. In addition to editorial changes the revisions include: Economic consideration of alternatives to pier protection; additional emphasis on protecting vessels against unwarranted damage; alternative preservative treatment for timber; and minor modifications to typical protection system details. Also one additional reference was added.

Shown below are only those portions where changes occur. Any additional or changed wording has been underscored and deletions indicated.

On Page 8-23-1, portions 23.2.1 Vessel and 23.2.2 Waterway have been changed as follows:

23.2 SPECIAL CONSIDERATIONS

23.2.1 Vessel

The size and type of vessel to be chosen as a basis for design of the pier protection should reflect the maximum vessel tonnage, <u>type of cargo</u> and velocity reasonably to be expected for the specific facility involved.

23.2.2 Waterway

Consideration should be given to the exposure of the structure in the waterway, including the alignment of the channel, visibility for approaching vessels, as well as effect of wind, ice, current or tide in the vicinity.

The economics of increased span length to reduce the chance of ship collision, by constructing piers in shallow water away from the waterway, may reduce or eliminate pier protection.

Depth of water and fluctuation of water level may dictate the type of protection to be chosen. If the depth is so great, or the character of the waterway bottom does not lend itself to proper anchorage and support for an independent protective system, it may be necessary to design a suspended or floating protective system.

On Pages 8-23-2 and 8-23-3, the section 23.3.1 General under DESIGN, is changed as follows:

23.3 DESIGN

23.3.1 General

Criteria for the design of protective systems cannot be specified to be applicable to all situations. Investigation of local conditions is required in each case, the results of which may then be used to apply engineering judgment to arrive at a reasonable solution.

In any type of pier protection system, general details should be designed to provide the following:

a. Adequate mass and resilience so that the railroad facility will not be vulnerable to damage from normal collision of marine traffic.

b. A smooth transition past the pier paying particular attention to protrusions and details that might cause unwarranted damage to a vessel.

c. Replacement of damaged parts.

d. Elimination of sparking upon vessel impact.

On Page 8-23-6 the first paragraph of Section 23.3.4.1 Sheet Pile Cell Dolphins, has been changed as follows:

23.3.4.1 Sheet Pile Cell Dolphins (see fig. 2).

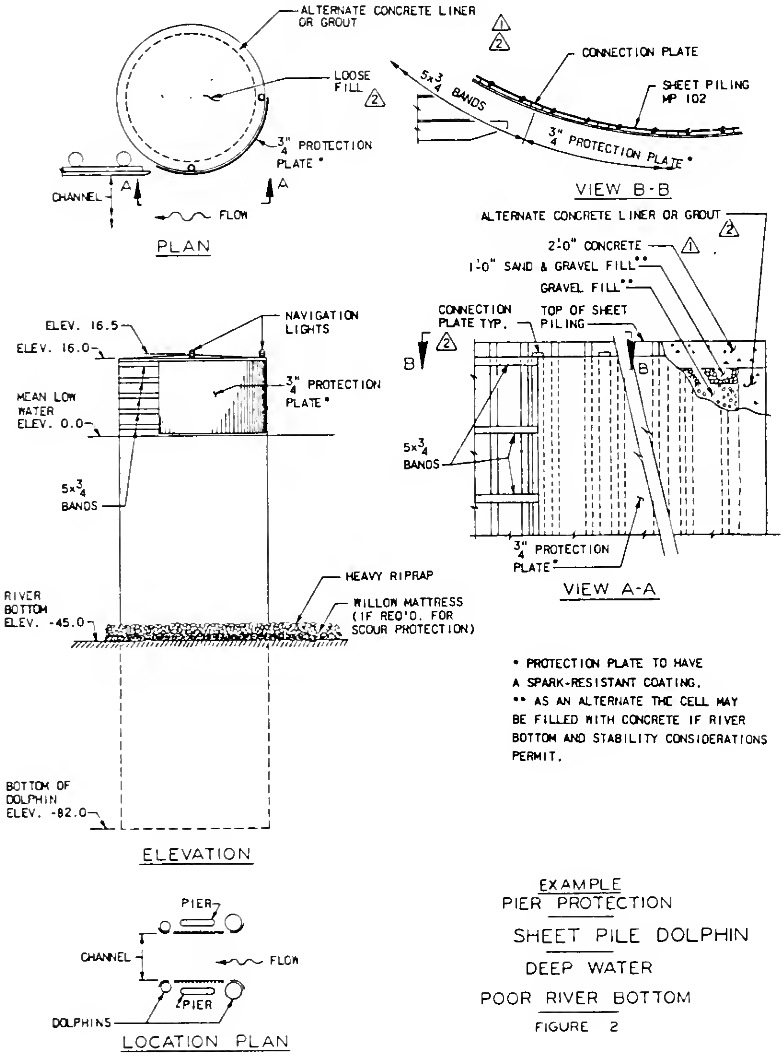
Sheet pile cells preferably should be of circular configuration. A typical cell includes interlocking steel sheet piles filled with concrete or grouted material. If loose fill materials are used, a concrete or grouted liner and a reinforced concrete top should be considered. (deletion here) The concrete top should be adequately anchored to the sheet piles. Desirable qualities of fill material include free draining characteristics, high unit weight, shear strength, and high coefficient of friction.

On Page 8-23-7 on the Plan, we have shown alternative concrete liner (loose fill), and on View AA we have shown the cap on the fill as 2-ft concrete, eliminating the word "bituminous" therefrom.

On Page 8-23-8, an authorized navigation clearance line has been added to the Elevation.

On Page 8-23-9, the detail for connection of the circular reinforced concrete cushion, shown on Plan, has been modified to current detail. Additionally on this sheet, we have noted that this type of protection is appropriate where there is "small variation in water level".

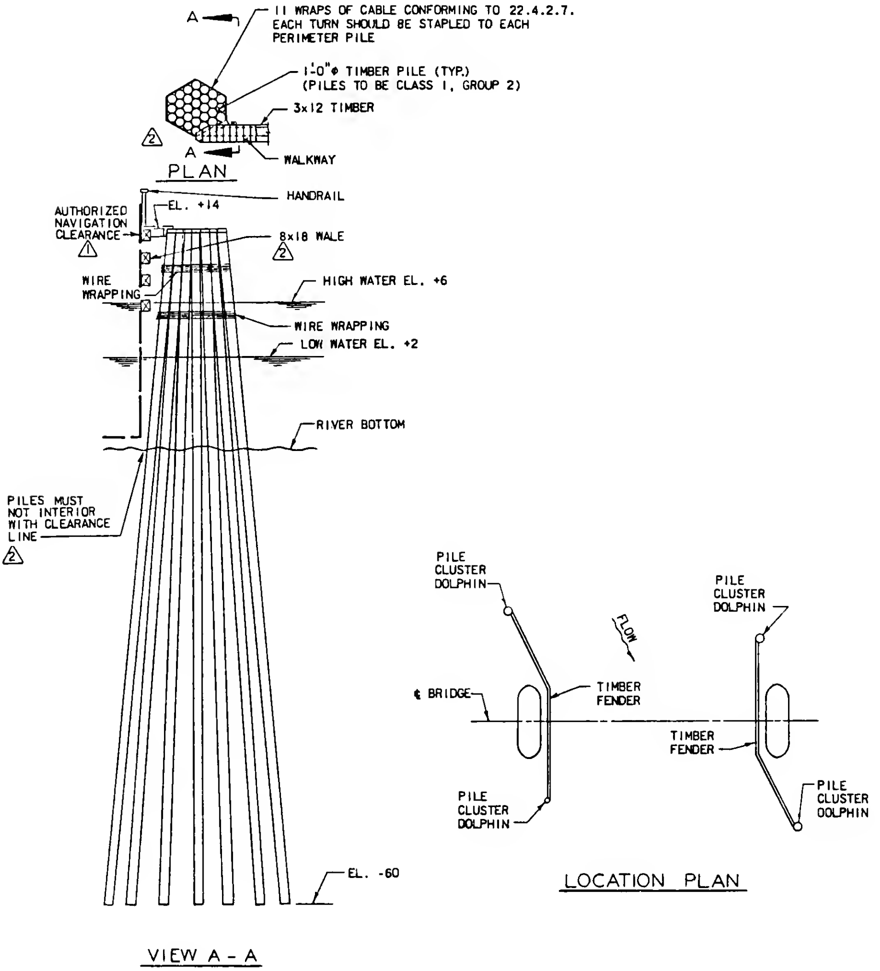
Copies of these three pages follow.



* PROTECTION PLATE TO HAVE A SPARK-RESISTANT COATING.
** AS AN ALTERNATE THE CELL MAY BE FILLED WITH CONCRETE IF RIVER BOTTOM AND STABILITY CONSIDERATIONS PERMIT.

EXAMPLE
PIER PROTECTION
SHEET PILE DOLPHIN
DEEP WATER
POOR RIVER BOTTOM
FIGURE 2

(1) CHANGE 3/30/84
(2) CHANGE 3/1/85

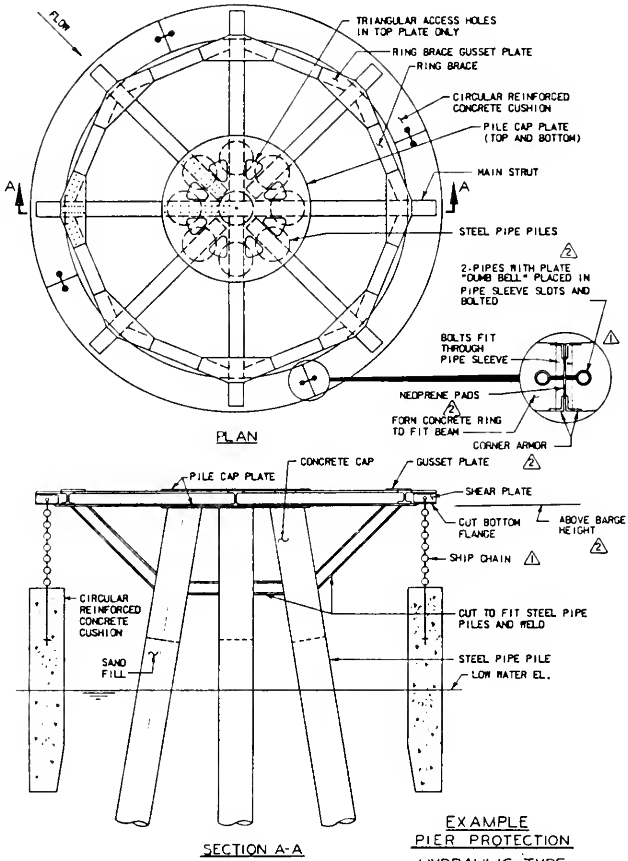


EXAMPLE
PIER PROTECTION

TREATED TIMBER PILE DOLPHIN

FIGURE 3

1 CHANGE 3/30/84
2 CHANGE 3/1/85



EXAMPLE
PIER PROTECTION
HYDRAULIC TYPE
HYDRO-CUSHION DOLPHIN

FIGURE 4

⚠1 NOTE:
FOR USE IN LOCATIONS WITH SMALL CHANGES IN WATER LEVEL AND BARGE TRAFFIC ONLY

⚠1 CHANGE 3/30/84
⚠2 CHANGE 3/1/85

On Page 8-23-16, subparagraph c. has been modified and subparagraph d. has been added under Section 23.4.2.1 Timber as follows:

23.4.2.1 Timber

c. Timber, except walkway planking and handrails, should be preservative treated with coal tar creosote by the full cell process, or other appropriate preservative. The preservative treatment should be in accordance with AREA Chapter 3, Parts 6 and 9 inclusive. Alternative preservative treatment is subject to approval of the engineer. Walkway planking and handrails may be treated either with creosote or pentachlorophenol. Pentachlorophenol should be used if the member is to be painted with exterior oil paints.

d. Timber should be treated with a fire retardant, if appropriate.

Also on Page 8-23-16, in subparagraph b. under 23.4.2.2 Timber Piles, the spelling of the word "conform" should be corrected.

On Page 8-23-21, the following should be added to the list of REFERENCES.

Committee on Ship-Bridge Collisions, Marine Board, Commission on Engineering and Technical Systems, National Research Council, 1983; Ship Collisions with Bridges, The Nature of the Accidents, Their Prevention and Mitigation.

Committee 10 - Concrete Ties

In the past year Committee 10 has submitted two separate recommendations for the Manual.

The first consisted of changes in the definitions for clarity along with two changes to structural steel requirements, a revised table of flexural strength for 2 block ties, changes to the testing procedures of monoblock ties for the fastening uplift test, rail seat repeated load test, and bond development, tendon anchorage and ultimate load test. For two block ties the following tests are being changed: Electrical Impedance Test, Center Negative Bending Moment test, Center Positive Bending Moment test, Fastening Uplift test and Daily Production Quality Control tests. The section on Ballast Reaction was also changed along with sketches on pages 10-1-44 and 10-1-45.

The second set of recommendations changed the sequence of tests for the tie block under two block ties, the Fastening Uplift test, the Fastening Longitudinal Restraint test and adds a new requirement of a tie pad test.

Most of these changes were brought about due to the committee's increase in knowledge from various field installations of concrete ties and test findings at Pueblo. The changes to the two block tie testing were necessary due to the Manual material dating to the Ad Hoc Committee days when little information was available.

Page 10-1-3

UNDER DEFINITIONS

5. Lateral Load - A load or component of a load at the gage corner of the rail parallel to the longitudinal axis of the tie and perpendicular to the rail.

7. Negative Bending - Bending that produces tension or reduces compression in the top surface of the tie.

8. Positive Bending - Bending that produces tension or reduces compression in the bottom surface of the tie.

9. Prestressing Tendon - A strand, wire or bar designed to precompress the concrete.

10. Prestressed Tie - A tie utilizing precompressed concrete and prestressing tendons.

14. Post-tensioning Tendon - Steel strands, wires or bars which are stressed subsequent to placement and hardening of concrete.

15. Pretensioning Tendon - Steel strands, wires or bars which are stressed prior to the placement of concrete.

16. Rail Seat - The area of a tie on which rail rests.

17. Reinforced Concrete Tie - A tie reinforced with deformed steel bars, welded wire fabric, deformed wire, or bar or rod mats and using non-precompressed concrete.

20. Vertical Load - A load or component of a load at right angles to a line joining the two rail seats of the tie and normal to the longitudinal axis of the rail.

Page 10-1-12

Section 1.2.3.12

Add subsection 1.2.3.12 (a) Structural steel used for the tie bar of two block ties shall be copper bearing and shall have a minimum thickness of 0.236 inches (6mm) in order to provide adequate corrosion resistance.

Section 1.2.3.13 Reinforcement Placement and Spacing.

The placement and spacing of reinforcement, prestressing steel and prestressing ducts shall be in accordance with all applicable requirements of the AREA Manual, Chapter 8, Part 1, Section 1.9.5. Spacing of Reinforcement, except that tolerances for placing shall meet the requirements of Art. 1.3.2.12.

Page 10-1-18

1.5 Flexural Strength of Two Block Ties.
1.5.1 Flexural Performance Requirements for Two-Block Designs

TABLE 11

REQUIRED FLEXURAL CAPACITY (INCH-KIPS)[3]

LENGTH TIE BLOCK INCHES	TIE[2] SPACING INCHES	RAILSEAT - POSITIVE[3]		RAILSEAT-NEGATIVE[4]	
		REINF. TIE	P/S TIE[1]	REINF. TIE	P/S TIE[1]
30	24	230	255	165	180
33	24	255	280	180	200
36	24	280	305	200	215

1. Prestressed or prestressed-reinforced.

2. Other flexural capacity values may be used for tie spacing other than 24 inches. These values are currently under study.

3. The values shown in the Railseat-Positive, P/S Tie column above, have been increased by 10% to allow for long-term losses in prestressed ties. The resulting values and the values shown in the Railseat-Positive, Reinf. Tie column above have been rounded off to the next larger increment of 5 inch-kips.

4. 0.7 X Railseat-Positive requirement rounded to the next larger increment of 5 inch-kips.

Page 10-1-21

Section 1.9.1.2(b) Fastening Uplift Test (described in Art. 1.9.1.10 parts (a) and (b))- Shall be performed on one rail seat.

Section 1.9.1.5 Rail Seat Repeated - Load Test

Following the vertical load test on rail seat B, the load shall be increased at a rate of at least 5 kips per minute until the tie is cracked from its bottom surface up to the level of the lower layer of reinforcement.

After removal of the static rail seat load necessary to produce cracking, and substitution of 1/4 inch-thick plywood strips for those shown in Figure I, the tie shall be subjected to 3 million cycles of repeated loading with each cycle varying uniformly from 4 kips to the value of 1.1P. The repeated loading shall not exceed 600 cycles per minute. If, after the application of 3 million cycles, the tie can support the rail seat load (1.1P), the requirements of this test will have been met.

Page 10-1-22

Section 1.9.1.8 Bond Development, Tendon Anchorage and Ultimate Load Test

(a) Pretensioned concrete ties shall be tested for bond development, and ultimate strength as specified below:

With the tie supported and loaded at rail seat A as shown in Figure I, a load increasing at a rate not greater than 5 kips per minute shall be applied until a total load of 1.5P is obtained (the load P shall be as determined in "Rail Seat Vertical Load Test" for positive moment).

If there is no more than 0.001-inch tendon slippage determined by an extensometer reading to 1/10,000, the requirements of this test will have been met. The measurement shall be made on the outermost tendons of the lower layer. The load shall then be increased until ultimate failure occurs and the maximum load obtained shall be recorded.

(b) Post-tensioned concrete ties shall be tested for tendon anchorage and utlimate strength as specified below:

With the tie supported and loaded as shown in Figure I, a load increasing at a rate not greater than 5 kips per minute shall be applied until a total load equal to 1.5P is obtained. If the tie can support this load for a period of 5 minutes, the requirements of this test will have been met. The load shall then be increased until ultimate failure of the tie occurs, and the maximum load obtained shall be recorded.

Page 10-1-23

Section 1.9.1.10 Fastening Uplift Test.

(a) An 18 to 20-inch piece of the proper section of rail shall be secured to one rail seat using a complete rail fastening assembly, including pads, bolts, clips and associated hardware, as recommended by the manufacturer of the rail fastening system. In accordance with the loading diagram in Figure V, an incremental load shall be applied to the rail. The load P (measured load plus unsupported tie weight plus frame weight) at which separation of the rail from pad or pad from rail seat occurs (whichever occurs first) shall be recorded.*

(b) The load shall then be completely released. A load of 1.5P not to exceed 10 kips shall then be applied. The inserts shall not pull out or loosen in the concrete and no component of fastening system shall fracture nor shall the rail be released.

Page 10-1-26

Section 1.10.1.2 (c) Electrical Impedance Test (described in Art. 1.10.1.15).

Section 1.10.1.3 Sequence of Tests (Tie Block)

The sequence of design performance tests using tie block shall be as follows:

(a) Tie Pad Test* (described in Art. 1.10.1.16).

(b) Fastening Uplift Test Part A (described in Art. 1.10.1.11).

(c) Fastening Longitudinal Restraint Test (described in Art. 1.10.1.13).

(d) Fastening Repeated Load Test (described in Art. 1.10.1.12).

(e) Fastening Longitudinal Restraint Test (described in Art. 1.10.1.13).

(f) Fastening Uplift Test Part A (described in Art. 1.10.1.11).

(g) Fastening Lateral Restraint Test (described in Art. 1.10.1.14).

(h) Tie Pad Test (described in Art. 1.10.1.16).

Page 10-1-27

Section 1.10.1.6 Center Negative Bending Moment Test

With the tie supported and loaded as shown in Figure VIII, a load increasing at a rate not greater than 5 kips per minute shall be applied until a load of 11 kips causing a moment of 55 inch-kips has been reached. If structural cracking does not occur on the gage faces of the blocks and the deflection at the center of the tie does not exceed 0.5 inch, the requirements of this test will have been met. Continue loading at the same rate until a load of 19 kips causing a moment of 95 inch-kips is reached and is held for five minutes. If structural cracking does not occur on the gage faces of the blocks and the permanent deformation of the tie bar recorded one minute after load removal is less than 1/4 inch, the requirements of this test will have been met.

Section 1.10.1.7 Center Positive Bending Moment Test

With the tie supported and loaded as shown in Figure IX, a load increasing at a rate not greater than 5 kips per minute shall be applied until a load of 11 kips causing a moment of 55 inch-kips has been reached. If structural cracking does not occur on the gage faces of the

*Test shall be conducted on three pads. The two pads providing highest and lowest spring rate values shall be used for tests (b) through (h).

blocks and the deflection at the center of the tie does not exceed 0.5 inch, the requirements of this test will have been met. Continue loading at the same rate until a load of 19 kips causing a moment of 95 inch - kips is reached and is held for five minutes. If structural cracking does not occur on the gage faces of the blocks and the permanent deformation of the tie bar recorded one minute after load removal is less than 1/4 inch, the requirements of this test will have been met.

Page 10-1-28

Section 1.10.1.11 Fastening Uplift Test

The Fastening Uplift Test shall be performed in two parts, (a) and (b), following the test procedure specified in Art. 1.9.1.10.

Section 1.10.1.13 Fastening Longitudinal Restraint Test

Both before and after the performance of the Fastening Repeated Load Test and without disturbing the rail fastening assembly in any manner other than retorqueing anchor bolts, the tie and fastening shall be subjected to a Longtudinal Restraint Test following the test procedure specified in Art. 1.9.1.12.

Section 1.10.1.16 Tie Pad Test

The Tie Pad Test shall be performed following the test procedure specified in Art. 1.9.1.15.

Section 1.10.2.1 Daily Production Quality - Control Tests

Delete Item (d) The Electrical Impedance Tests.

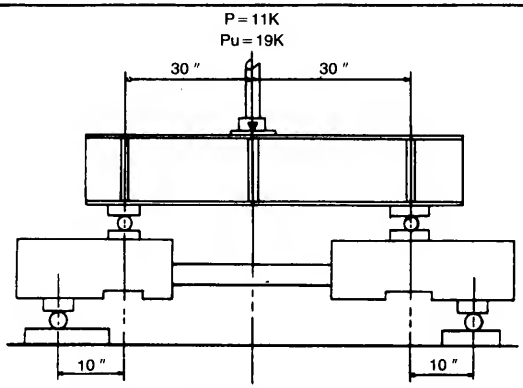
Page 10-1-36

Section 1.13.2.1 Ballast Reaction

Revise last paragraph to read:

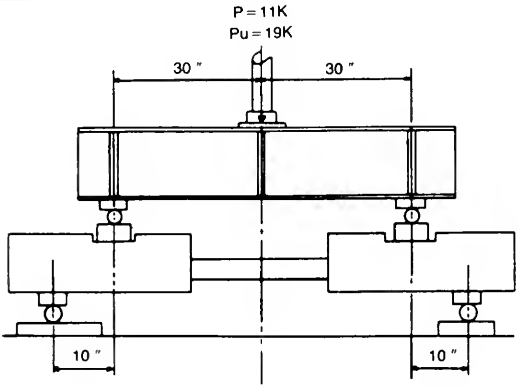
Flexural requirement for three lengths of tie blocks for a tie spacing of 24 inches are shown in Table II. Flexural requirements for block length other than those shown may be calculated but in no case should the rail seat positive flexural capacity be less than 230 inch-kips.

Page 10-1-44



TWO BLOCK TIE CENTER NEGATIVE BENDING TEST FIGURE VIII

Page 10-1-45



TWO BLOCK TIE CENTER POSITIVE BENDING-TEST FIGURE IX

Committee 15 - Steel Structures

Committee 15 has recommended revisions to Parts 1, 2, 5, 6 and 8 of Chapter 15.

Tables 1.2.1, 1.14.7, and 2.2.2 in Parts 1 and 2 are to be revised to conform to the latest ASTM A709 Specifications with suffix "F" covering material in fracture critical members and "T" for non-fracture critical members.

TABLE 1.2.1—IMPACT TEST REQUIREMENTS FOR STRUCTURAL STEEL—OTHER THAN FRACTURE CRITICAL MEMBERS[1,2,4]

ASTM Designation	Thickness, in.	Minimum Average Energy, Ft Lb, and Test Temperature		
A36 or A709. Grade 36T[5]	Through 6	15 @ 70°F	15 @ 40°F	15 @ 10°F
		0°F	—30°F	—60°F
		Minimum Service Temperature[3]		

[1]Impact tests shall be in accordance with the Charpy V-notch (CVN) tests as governed by Specification A673 with frequency of testing as follows:

(a) For plate material not thicker than 1-1/2 in., frequency H.

(b) For plate material thicker than 1-1/2 in., frequency P.

[2]Impact requirements in Table 1.2.1 are the same as those given in A 709, Supplementary Requirement S3, Table 7. A 36, Supplementary Requirement S2, provides for silicon-killed, fine-grain practice, where desired. A 709, supplementary requirement S1, provides for killed steel, fine grain practice, where desired.

[3]Minimum service temperature of 0°F corresponds to Zone 1.—30°F to Zone 2, —60°F to Zone 3, referred to in Article 9.1.2.1.

[4]Impact test requirements for structural steel of Fracture Critical Members are specified in Table 1.14.7.

[5]The suffix "T" indicates material to be used in a non-fracture critical member.

TABLE 1.14.7—IMPACT TEST REQUIREMENTS[1] FOR STRUCTURAL STEEL - FRACTURE CRITICAL MEMBERS

ASTM Designation	Thickness, In.	Minimum Average Energy, Ft-Lb and Test Temperature		
A 36 or A 709, Grade 36 F	Through 1-1/2	25 @ 70°F	25 @ 40°F	25 @ 10°F
	Over 1-1/2, Through 4	25 @ 50°F	25 @ 20°F	25 @ -10°F
A 572, Grade 50[2] or A 709, Grade 50F[2,5]	Through 1-1/2	25 @ 70°F	25 @ 40°F	25 @ 10°F
	Over 1-1/2, Through 2	25 @ 50°F	25 @ 20°F	25 @ -10°F
A 572, Grade 60[3]	Through 1-1/4 Mechanically Fastened	25 @ 70°F	25 @ 40°F	25 @ 10°F
A 588 or A 709, Grade 50WF[2,5]	Through 1-1/2 Mechanically Fastened	25 @ 70°F	25 @ 40°F	25 @ 10°F
	Over 1-1/2, Through 4 Mechanically Fastened	25 @ 50°F	25 @ 20°F	25 @ -10°F
	Through 1-1/2 Welded	25 @ 70°F	25 @ 40°F	25 @ -10°F
	Over 1-1/2, Through 2 Welded	25 @ 50°F	25 @ 20°F	25 @ -10°F
	Over 2, Through 4 Welded	30 @ 50°F	30 @ 20°F	30 @ -10°F
		0°F	-30°F	-60°F
		Minimum Service Temperature[4]		

[1]Impact tests shall be in accordance with the CVN tests as governed by ASTM Designation A 673, for frequency of testing P. Impact tests shall be required on a set of specimens taken from each end of each plate.

[2]If the yield point of the material exceeds 65 ksi, the test temperature for the minimum average energy required shall be reduced 15°F for each increment or fraction of 10 ksi above 65 ksi.

[3]If the yield point of the material exceeds 75 ksi, the test temperature for the minimum average energy required shall be reduced 15°F for each increment or fraction of 10 ksi above 75 ksi.

[4]Minimum service temperature of 0°F corresponds to Zone 1, -30°F to Zone 2, -60°F to Zone 3 referred to in Article 9.1.2.1.

[5]The suffix "F" indicates material to be used in fracture critical members.

TABLE 2.2.2—IMPACT TEST REQUIREMENTS[1] FOR HIGH STRENGTH STRUCTURAL STEEL—OTHER THAN FRACTURE CRITICAL MEMBERS[4]

ASTM Designation	Thickness, In.	Minimum Average Energy, Ft-Lb, and Test Temperatures		
A 441	Through 4	15 @ 70°F	15 @ 40°F	15 @ 10°F
A 572, Grade 50[2] or A 709, Grade 50T[2,5]	Through 2			
A 588[2] or A 709, Grade 50WT[2,5]	Through 2 Over 2, Through 4	15 @ 70°F 20 @ 70°F	15 @ 40°F 20 @ 40°F	15 @ 10°F 20 @ 10°F
		0°F	-30°F	-60°F
		Minimum Service Temperature[3]		

[1]Impact tests shall be in accordance with the Charpy V-notch (CVN) tests as governed by Specification A 673 with frequency of testing as follows:

(a) For plate material not thicker than 1-1/2 in., frequency H.

(b) For plate material thicker than 1-1/2 in., frequency P.

[2]If the yield point of the material exceeds 65 ksi, the test temperature for the minimum average energy required shall be reduced 15°F for each increment or fraction of 10 ksi above 65 ksi.

[3]Minimum service temperature of 0°F corresponds to Zone 1, -30°F to Zone 2, -60°F to Zone 3, referred to in Article 9.1.2.1.

[4]Impact test requirements for structural steel of Fracture Critical Members are specified in Table 1.14.7.

[5]The suffix "T" indicates material to be used in a non-fracture critical member.

To bring paragraph 5.1.3.3(b) in Part 5 into conformity with AWS D1.1, revise "grades 1015 or 1020" to read "grades 1010 thru 1020".

Paragraph 6.2.10(b) in Part 6 is to be revised to call for an elevator at each tower on span-drive, as well as, tower-drive vertical lift bridges.

Change Article 6.2.10(b) to read:

(b). "An elevator shall be provided at each tower of vertical lift bridges for all tower drive bridges and for span drive bridges where service platforms are 50-ft. or more above track level. Elevators shall be capable of carrying personnel and maintenance equipment from track level to the machinery level at the tops of the towers. The elevator cars shall be fully enclosed with solid sides and roof. They shall have a net floor area of not less than 12 sq. ft. and a capacity of not less than 1,200 lb."

Article 8.6 "Guidelines for Evaluating Fire Damaged Steel Railway Bridges" in Part 8 is to be amended to simplify the temperature table and add a color/temperature table.

Change to Article 8.6.6 by adding subarticle (e) as follows:

"The maximum temperature reached during the fire may be estimated by testimony of competent observers as to the color of the steel during the height of the fire. Such temperature estimates would be accurate only within a range of a few hundred degrees. The following table may be used to correlate color with temperature:

750°F	Red heat, visible in the dark
900	Red heat, visible in twilight
1000	Red heat, visible in daylight
1300	Dark red
1500	Dull cherry red
1800	Bright cherry red

An alternate guide is the Heat-Color Poster available from the American Society for Metals."

COMMITTEE 33—ELECTRICAL ENERGY UTILIZATION

Committee 33 has recommended a new Part 8 of Chapter 33. New Part 8 "Catenary and locomotive interaction" provides a more complete understanding of the interactions between catenary/power supply system and the locomotive and its power control system. This section includes articles on the electrical characteristics of locomotives, types of traction motor control circuits, and basics of the pantograph system.

Part 8

Catenary and Locomotive Interaction

8.1 LOCOMOTIVE ELECTRIC INTERACTION WITH THE CATENARY

8.1.1 INTRODUCTION

The catenary and power supply system interact with the locomotive and its power control system. The modern series of thyristor controlled locomotives provide various forms of distortion to the current drawn from the power supply. There is also a mechanical interaction between the catenary and pantograph power collection systems. This part of the manual is intended to promote a more complete understanding of these interactions.

8.1.2 ELECTRICAL CHARACTERISTICS

In A.C. input locomotives, a transformer is used to convert high voltage (12.5, 25 or 50 KV) to levels more compatible with the control equipment and the traction drive motors.

The transformer output voltage must be varied to provide for speed and power changes in the traction motors. Modern systems use various combinations of semiconductors such as diodes, thyristors (SCRs) and transistors for power control. All of these devices generate harmonics on the secondary side of the transformer which may be coupled back thru the primary to the catenary where it can radiate and cause interference with communication wires. The harmonics are also directly coupled into the rails and can cause signal interference. Particular care must be taken to avoid even order harmonics due to the tendency for translation into a D.C. component.

The magnitude of harmonics generated is a function of the type of power control circuit used. One of the most influential factors affecting the harmonics present on the catenary is the transformer impedance or degree of coupling between primary and secondary. High impedance tends to minimize harmonic generation and also limit fault current on the system; however, this also raises the size and weight of the transformer and adversely affects power factor. The system designer has the problem of achieving the best compromise between conflicting requirements. Care must also be taken, in the transformer design, to ensure that the initial inrush current when first energizing a transformer or when reenergizing after a momentary interruption, is coordinated with the catenary system.

Secondary filters are frequently used to control harmonics, and also to improve power factor. Care must be taken, however, to avoid resonances with the power distribution system either on a power system frequency basis or from the impulse type excitation which the semiconductor voltage control system generates.

In addition to the conventional lightning arresters on the roof of the locomotive, protection is required on the secondary windings, against transients generated by substation switching, pantograph bounce, and operation thru dead sections.

8.1.3 TYPES OF TRACTION MOTOR CONTROL CIRCUITS

Refer to Figure 1 for simplified circuits.

8.1.3.1 Diode Bridge Rectifier

The single bridge connection may be used to provide a DC source for a non-line synchronized motor controller such as a DC chopper or variable frequency AC invertor or to supply power for the traction motors without intermediate controls.

The output of such a bridge must be filtered to reduce the ripple voltage fed to the traction motors directly or to the variable voltage/frequency device such as a chopper or invertor. If fed directly to the motors, some kind of tap changing at the transformer is necessary since the diodes by themselves are not capable of varying voltage. The filter is normally a simple inductance/capacitance type.

The capacitor acts also as a source for high peak currents required by the forced-commutation circuits of an invertor or chopper. The effect of the high frequency commutations on the catenary system are reduced by the filter effect of the capacitor bank, transformer reactance and other inductances in the system. Small high frequency current spikes generated when the diodes block at the end of their conduction period have to be minimized by L-R-C snubber circuits mounted on each diode.

Power factor of a diode bridge is high, roughly in the 90% area. Correction above this limit by means of capacitors must be done with great care so as to avoid system resonance problems which can vary with the distance between locomotive and substation.

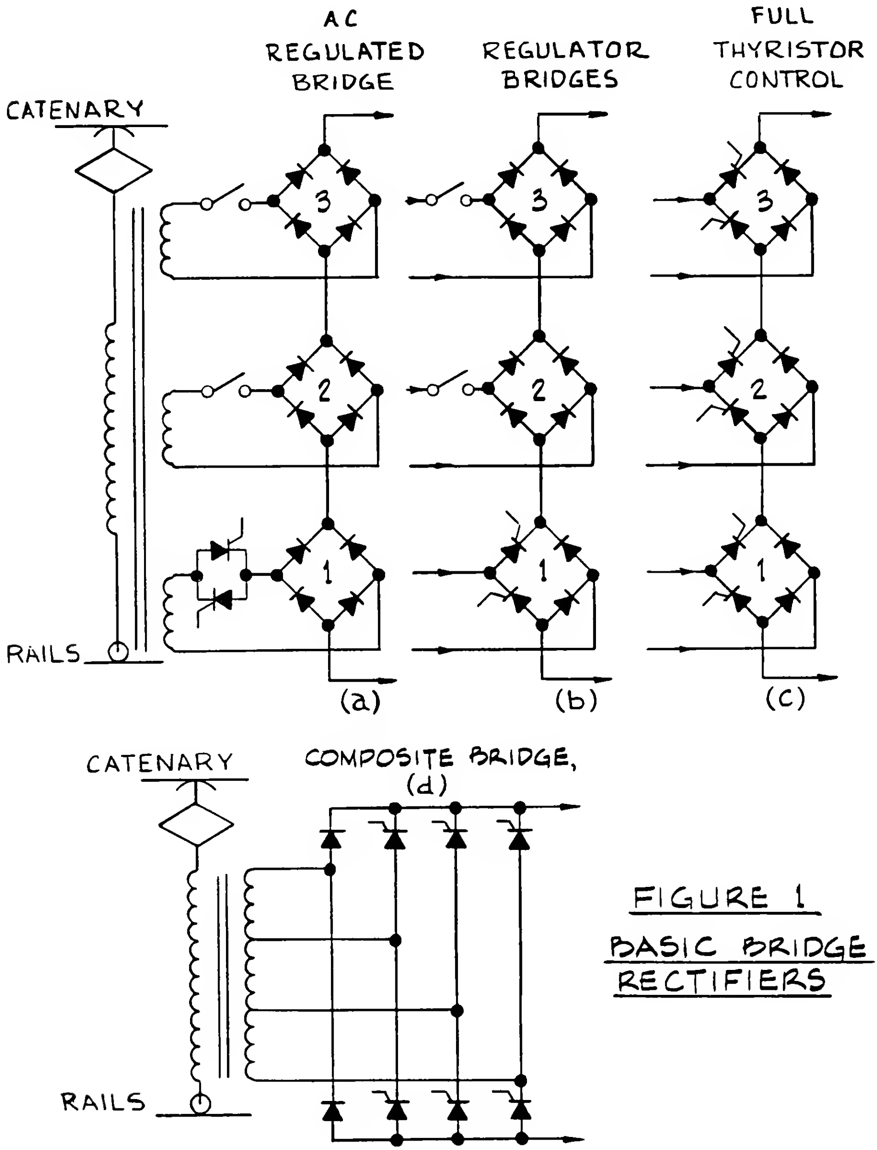


FIGURE 1

BASIC BRIDGE RECTIFIERS

8.1.3.2 Thyristor Controlled Bridge

A thyristor can be turned "ON" by its control electrode called a "gate" but will not turn "OFF" unless the voltage across the anode/ cathode connections is reversed. In a line powered rectifier, the voltage is automatically reversed at the end of each half-cycle and the thyristor turns off naturally. In an invertor or DC chopper application, with a DC supply link, no reversal of voltage occurs and the thyristor has to be "force commutated" by an external commutating.circuit. Typically, the current has to be reversed for 25 to 50 microseconds to turn off a thyristor. The rates of change in current, at commutation, may be of the order of 100 Amps/ microsecond at levels up to triple the peak load current. Considerable electrical noise is radiated by this type of switching activity; furthermore, it is at a repetition rate that can vary as the load changes.

A thyristor controller is a diode/thyristor combination where the output power is controlled by adjusting the time during the line cycle at which thyristor conduction occurs. This type of controller can be used to drive the traction motors directly and the minimum current requirement of the components is the maximum required for the motors. A basic thyristor controller has inherently poor power factor which can be improved by use of several bridges added in series. There are various combinations, of three bridges shown in Figures 1(a)(b) with alternative arrangements shown in Figures 1(c) (d), where all bridges are under thyristor control and addition or subtraction of voltage is sequentially controlled. Idealized waveforms of the voltage increase mode obtained by phasing on, or adding rectifiers, in sequence are shown, for one half cycle, in Figure 2.

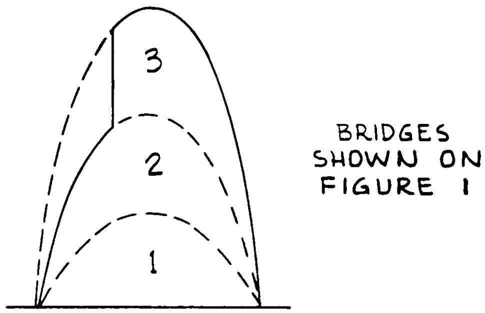


FIGURE 2

BRIDGE OUTPUT VOLTAGE

At the time in each cycle when the thyristors start conduction, fast switching transients are developed. The rate of change in current is controlled by inductances of transformer windings and by bus bar reactances. Filtering is fitted across the transformer windings to reduce telephone interference (TIF) caused by higher order harmonics, and also absorb high frequency transients. Consequently, fast rates of change which occur at the thyristor should not feed back to the line current. The distribution of the various harmonic components will vary with the point of conduction in the cycle. At low speeds the power factor will be poor due to basic action of the phase control function. In addition, due to high motor current at low speed, reactive current overlap into the next half-cycle can be quite extensive which also degrades the power factor. Overlap is also a function of the coupling between transformer windings.

A thyristor bridge may also be used as a DC supply to a chopper or invertor at fixed voltage in cases where variations in catenary voltage are encountered.

8.1.3.3 Chopper

A chopper supplies pulsed DC to a load, such as a traction motor, by turning on and off a DC supply voltage. This DC supply must be capable of supplying pulses of current with a very low voltage drop; this is the function of the line filter (see Figure 3) capacitor C_1. The inductor, L_1, supplies a constant current I_1 to the load and capacitor. Since I_1 is a DC current proportional to the average of the pulses I_3 supplied to the motor, the chopper has the unique characteristic of having the transformer secondary current proportional to the KW of the load which is not directly related to motor current, in effect, a DC transformer.

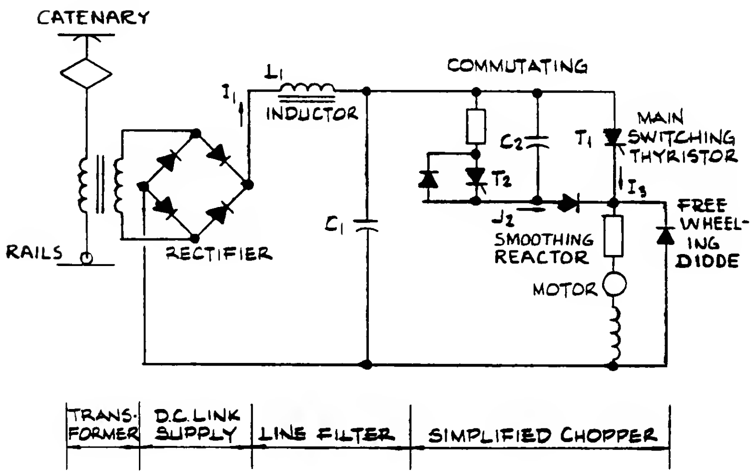


FIGURE 3

D.C. CHOPPER SYSTEM

This, plus the effective isolation of the chopper harmonics by the line filter, allows inherent power factors in the 90% range and very low harmonics.

There are many locomotives which could benefit from power factor and performance improvement. For retrofit purposes, a DC chopper can offer a good economic alternative to the thyristor controller or AC invertor. Most applications so far have been addressed to the use of chopper controls from a DC catenary or third rail where the chopper can be used as a direct link with the motor. Major difference between an AC invertor and a DC chopper lies in the filtering permitted in the connection to the motor. In a three-phase drive, the motor feed can be filtered and wiring to the motor does not become part of the active commutation process. In a chopper configuration, the motor is more closely tied in to the commutation circuitry.

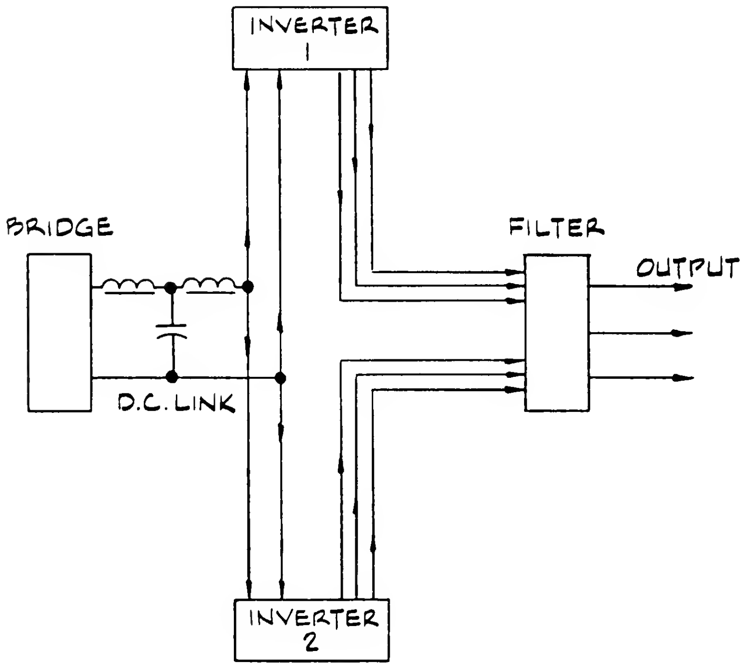


FIGURE 4

LOCOMOTIVE SYSTEM

In addition, for transit applications, the equipment is mounted under the main body of the transit car with less enveloping metal work to provide a shield. Careful attention to vehicle construction details should minimize potential problems.

Variable speed industrial drives using asynchronous motors have been in use for almost 20 years with designs specifically dedicated to high power traction applications for locomotives. The most popular technique is Pulse-Width Modulation (PWM). In PWM, a carrier frequency of approximately 500 Hz is time modulated to provide a variable frequency source varying typically from one to 70 Hz. Individual thyristors switch at the 500 Hz rate (Figure 5). A PWM design requires thyristors with a fast turn-off characteristic for an efficient range of modulation.

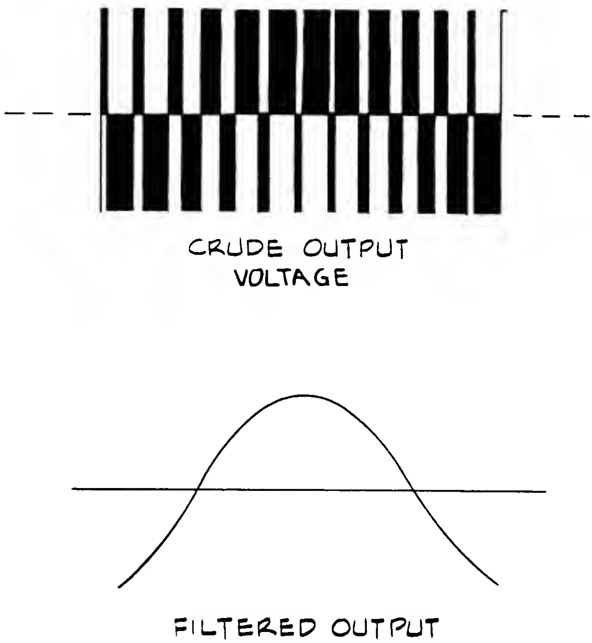


FIGURE 5

PWM WAVEFORM

An alternate system uses one or more three phase invertors (Figure 6) operating at the output frequency of the system. For comparison with the PWM system, basic switching repetition for individual thyristors would be 0 to 70 Hz. Switching periods at the lower rate allow more latitude on turn-off time so that a softer commutation can be used with less sophisticated thyristors. An inductor is normally in series with the DC capacitor bank and tends to keep current levels relatively constant. This leads to the label "Constant Current" invertor (CCI) as compared with the constant voltage concept of a PWM system. From an EMI point of view, the PWM system with high circulating current and fast rates of change is potentially a more active source of EMI than a CCI system.

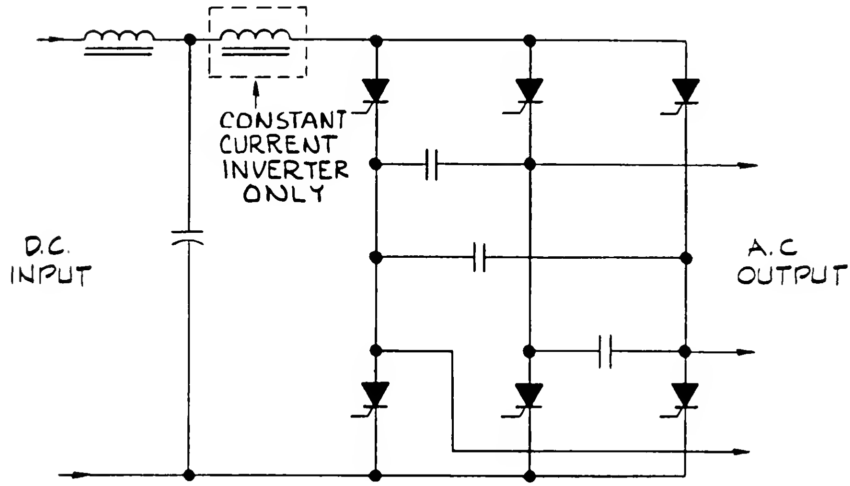


FIGURE 6

GREATLY SIMPLIFIED INVERTER

8.1.3.5 Auxiliary A.C. and Head End Power For Passenger Equipment

On electric locomotives up to 800 KVA of three phase power may be generated by thyristor invertors for use in the locomotive and to provide power to passenger cars (when required). Power from the catenary passes thru the transformer to a thyristor controlled bridge arrangement for voltage control. The invertors consist of three-phase bridges for optimum reduction of harmonics. Output from the invertors is typically 175 KVA auxiliary power for the locomotive and 625 KVA for the passenger cars. Power to the passenger cars may have additional L-C filters for harmonic reduction.

Any fast transients generated are reduced by the AC filter on the locomotive and are not transmitted to the passenger cars.

Although experience is limited, no serious interaction with cab signalling or railroad communications has been experienced.

Invertor components are contained in robust compartments inside the body of the locomotive, wiring runs and power connections are minimized to reduce stray emissions. Wiring is segregated to avoid stray pickup and is within the main body of the locomotive. The external skin of the locomotive itself acts as a totally enclosed ground shield to further attenuate commutation current radiation or similar interferences escaping to the external environment.

8.1.3.6 General Requirements

There are many thyristor based circuits which provide similar results. Choice of type for a particular application will be made based upon economics and individual manufacturers preference. The power factor (PF) characteristic will be of the form shown in Figure 7 for a series motor connection. When, however, field weakening is allowed, it permits a more optimum PF performance over a wider speed range of the curve. The number of bridges used to make up the converter is a function of the type of duty for which the locomotive is intended. For high speed passenger service, a lower power factor may be accepted at low speed as the operating time under that condition will be mostly transitory in nature. Satisfactory operation with a two-bridge converter may be obtained when used in conjunction with field weakening.

Freight operation, however, requires a locomotive to haul at low speeds for most of its service life. For satisfactory PF performance with a thyristor converter more bridges would be required than for the passenger unit assuming no other means to improve power factor have been employed. Most passenger trains accelerate out of the poor power factor range in a very short time compared with a freight train.

As more semiconductor bridges are used, the amount of transient disturbance at thyristor conduction reduces and eases the requirement for EMI filtering. Cost will tend to be higher as the converter and control electronics increase with a reduction in overall reliability. In turn, however, an extra degree of redundancy could be built into the design as compensation, so that a failure on one winding can be bypassed.

Variations in the basic thyristor phase control circuit are possible to improve power factor. One such is a "forced commutation" arrangement shown in Figure 8.

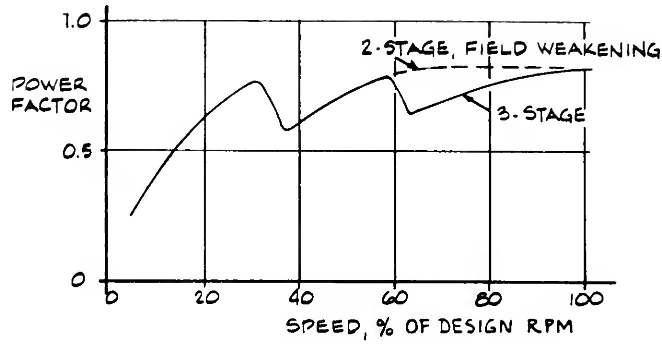


FIGURE 7

IDEALIZED SPEED-POWER FACTOR

FOR FIGURE 1 3 RECTIFIERS SEE 3 STAGE CURVE

FOR 2 RECTIFIER WITH FIELD WEAKENING SEE 2 STAGE CURVE

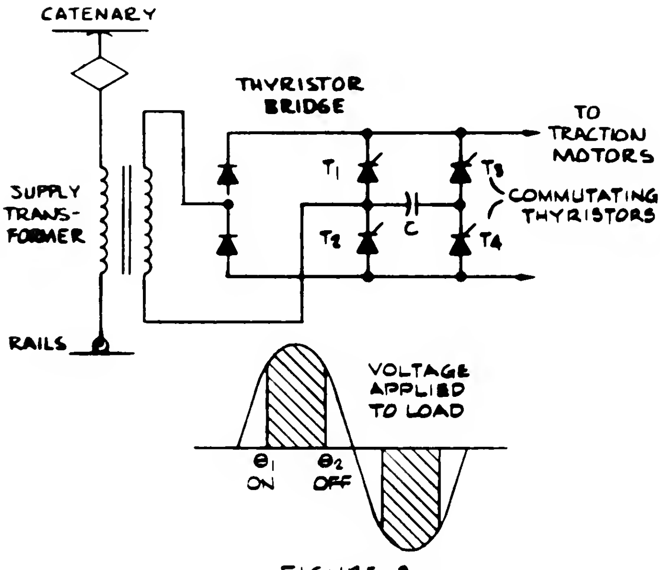


FIGURE 8

THYRISTOR FORCED COMMUTATION

The two thyristors, T_1 and T_2 operate in a normal phase control manner and initiate conduction at $\emptyset_1$. The capacitor, C, stores energy which is then used to force T_1 or T_2 off when T_3 or T_4 are turned on at phase angle $\emptyset_2$.

Centering the applied voltage pulse as described moves the current into phase with the voltage, resulting in a considerable improvement in power factor. Power factors of 94% are possible without the dangers of resonance problems inherent in large blocks of capacitors.

Power factor has to be considered very carefully in each application. The effect on long-term power costs and the utility company are easily understood. A more serious situation occurs, however, when considering voltage at the locomotive pantograph. The combination of low power factor and long catenary sections may result in a very low voltage applied to the locomotive. This has to be take into account when coordinating the locomotive characteristics with the catenary system and sub-station locations.

8.2 LOCOMOTIVE MECHANICAL INTERACTION WITH THE CATENARY

8.2.1 PANTOGRAPH BASICS

The requirement for reliable electric train operation has led to much study of the interaction of pantograph and overhead catenary equipment, throughout the world. The following guidelines present a basic design philosophy which allows for both locomotive and wayside requirements.

A pantograph is required to collect current from an overhead wire which has low mass, and may have substantial variations in wire height and gradient at tunnels, bridges, and road crossings. For good current collection, the contact between pantograph and overhead wire should remain relatively stable with less than 1% loss of mechanical contact up to maximum operating speed.

Climatic conditions should be taken into account and if severe icing will be encountered, then provision should be made for compensation in uplift. Care should also be taken to minimize collection of ice and snow to prevent locking up joints and bearings.

The pantograph should be designed to be sacrificial in the event of an entanglement with the catenary wire. Remaining parts of the pantograph attached to the locomotive should have an extended maximum height below the catenary support arms to reduce the potential for damage to the permanent structures.

In addition, the pantograph must be electrically satisfactory for the specified current and voltage, and operate in all weather conditions in an exposed and sometimes severe environment. The design must be as simple and robust as possible.

The pantograph should be bi-directional and aerodynamically neutral since the overhead line is designed for a specific mean uplift pressure. Current collection can be significantly degraded if the pressure is changed by airflow at speed. Poorly compensated pantographs running at 125 mph can show uplift variations of ± 50%.

Moving structural members should preferably be of rounded cross section for aerodynamic efficiency to minimize the effects of both locomotive speed and side winds.

The main-frame structural frequencies should be suitably damped to avoid excitation resonances from overhead line stagger and from the locomotive or power car suspension frequencies.

Suitable collector head suspension must be provided to reduce further the effective dynamic mass at hanger-passing frequency and at discrete features such as registration arms, overlaps, and neutral sections (phase breaks). The suspension response must be faster than the main-frame response to provide initial reaction to these low amplitude discontinuities.

Care must be taken, during the design, to ensure that the pivot points for the collector head provide positive contact on front and rear carbon strips over the operating speed range and in both directions.

Mass of the collector head must be minimized to allow the best possible tracking of contact wire irregularities at splices or points of localized wear. Since minimal weight is beneficial carbon carriers may use hollow section aluminum alloy extrusions with appropriate cross-sectional shape for good aerodynamics. Horns can be light tubular steel or aluminum alloy castings.

PORTFOLIO RECOMMENDATIONS
COMMITTEE 5—TRACK

Committee 5 recommends the following plans be revised: 616-83, 617-83, 618-83, 619-83, 620-83, 621-82, 622-82, 623-82, 624-82, and 625-82.

Some railroads using the A.R.E.A. slope area of the depressed heel on their maganesse insert frogs, have experienced unusual crushing in this area due to the remaining narrow running surface. The proposed revision will alleviate this situation with a uniform 2½ inch wide running surface adjacent to the depressed heel area.

CONSIDERATIONS OF FACTORS AFFECTING BALLAST PERFORMANCE

AAR Research and Test Department Report No. WP-110

S. M. Chrismer*

EXECUTIVE SUMMARY

One of the barriers to the development of a new ballast specification is the general disagreement over which properties are more important to ballast life. This problem is further complicated by confusion over which tests are more appropriate for testing a particular property. There is also the question of the realistic limits to be imposed on the test values. It would be of interest to be able to look at each aspect of a ballast and determine its contribution to the overall ballast performance. This paper presents the results from an extensive literature search for findings of this nature.

Some research results have indicated that certain tests are more relevant to ballast performance than others. Similarly, other research has shown certain tests to be superior in characterizing a particular ballast parameter. Of special interest is any research into ballast field performance that is compared with laboratory test results. One such study yielded interesting conclusions. Based on this study of ten ballast materials, the author concluded that ballast tests should evaluate the following four parameters, which appear to be the most common contributors to ballast failure: hardness, toughness, particle shape and weathering resistance.

* Research Engineer - Track, AAR, Research and Test Department.

1.0 INTRODUCTION

The current tests for ballast quality and their recommended values reflect relative measurements of durability that are not directly related to in-track performance. To illustrate how present tests often fail to provide good measures of performance, results from the British Crushing Value and Los Angeles Abrasion tests are compared to the percent deviation of track profile and alignment for each of five ballast types in Figures 1(a) and 1(b). It should be noted that these ballast durability tests were not indicative of the relative degree of performance observed in the field.

Laboratory performance tests for ballast do not yet exist. As stated by Hay, et al. [1]:*

> An unsolved problem remains of developing transfer functions whereby the length of ballast renewal cycles and intermediate maintenance cycles can be related to the relative stability characteristics of subgrade and ballast materials established by laboratory tests and related specifications.

The problem remains because we choose to perform many different tests to characterize ballast durability without knowing which tests are more relevant to field behavior. In addition, as field behavior is not understood sufficiently, there is not enough information for feedback to establish priorities for ballast properties.

Another reason that Hay's "unsolved problem" remains is that it implies a ballast life and an intermediate maintenance life. (The definitions of, and distinctions between, these two lives

* Numbers in square brackets [ ] concern the References, listed in Section 5.0 of this report.

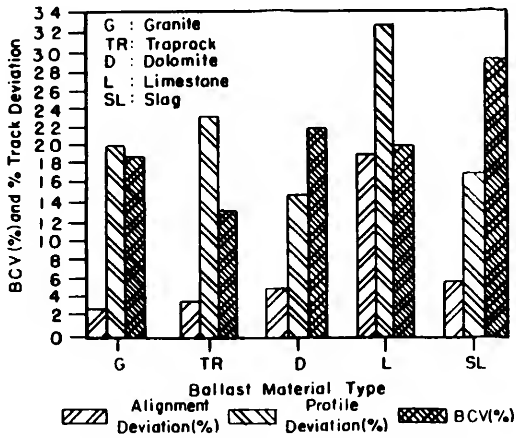


Figure 1 (a). British Crushing Value Versus Track Alignment and Profile Deviations.

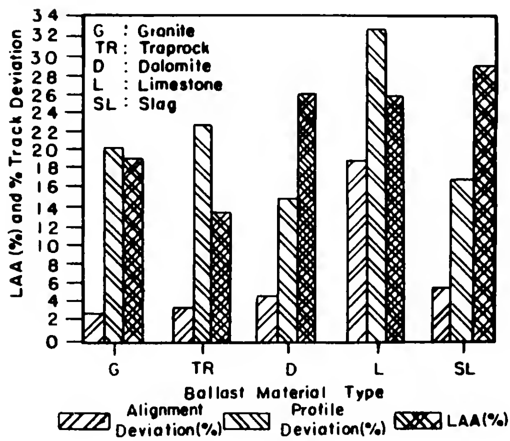


Figure 1 (b). Los Angeles Abrasion Value Versus Track Alignment and Profile Deviations.

are grounded in the economics of continued maintenance of old ballast versus replacement with new ballast. Since the information for such an economic model is seldom available, the judgement used to decide whether to rework or to replace the ballast is often very subjective.) Since ballast life is undefined, there is no definitive way to determine ballast maintenance or renewal cycles. In fact, Maintenance of Way engineers usually do not think in terms of a ballast life. If a ballast fails, the engineer is more likely to assume that the ballast specification tests were inadequate, rather than consider that the ballast has simply "worn out." However, even when materials have true performance-related tests as specification tests, they cannot be expected to have an infinite life. Once we have a better idea of how and why ballast fails, we may develop more rational tests, or modify existing ones, in order to better assess the appropriate properties that contribute to or resist such failures.

One way to determine why ballast fails is to conduct field investigations where the ballast has not performed well.

If the reasons for the poor performance can be discerned and compared to the original ballast properties, they can then be used to determine which properties are more relevant to ballast stability.

Ballast maintenance or renewal life can only be judged by more appropriate tests, such as those that reproduce the actual loading environment. One approach to this has been used by Norman and Selig, who developed a ballast box that simulates repetitive train loadings under a tie [2]. One important finding, to be discussed later, is the development of residual pressures in the ballast after a few load repetitions. This phenomenon would probably not have been discovered by use of the more traditional laboratory tests. Similar types of more realistic and modern laboratory tests should be encouraged.

Knowledge of ballast life implies a knowledge of the rate at which ballast loses its ability to perform one or more of its functions. This is a difficult task, since one must know the environmental conditions and loading patterns in order to obtain a good approximation of this rate. Tests which simulate the field loading environment (such as Selig's ballast box) can help, because they represent a link between the field and the standard durability tests. Better laboratory tests, along with more field tests of ballast performance in different environments, should help to provide the answers to the problem of which Hay speaks.

In the sections that follow, each of the ballast material properties that is thought to be relevant to ballast behavior is discussed. Also included are discussions of possible methods for testing those properties and previous research relative to ballast behavior.

2.0 BALLAST PARAMETERS

2.1 Ballast Material Types

The mineralogical properties of ballast can greatly affect its performance. As a rule, traprock is better than limestone. But the generic aggregate type is not sufficient to judge the quality of a ballast, since there may be a large overlap in strength between any two types. Figure 2 illustrates how the uniaxial compressive strength for limestone and granite may overlap [3]. There is also the complication of determining the material type itself. The names commonly in use often do not indicate sufficient information about the rock properties, because these can vary greatly within a certain rock type. For example, the term "gravel" tells very little about the material type; its origin may be sedimentary, igneous, metamorphic, or a combination of these.

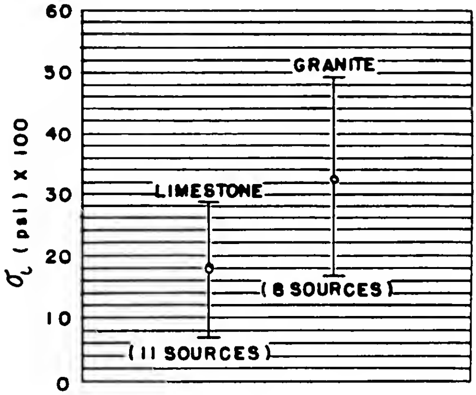


Figure 2. Ranges of Unconfined Compressive Strength for Limestone and Granite.

Just as some materials are classified too broadly, some have classifications based on slight differences. For example, limestone and dolomite differ mainly because the latter has significantly more magnesium than the former. This results in dolomite possessing, on average, more strength than limestone. However, due to great variability within each rock type, a particular limestone may have higher strength than a particular dolomite. Thus these materials should be assessed on their individual properties rather than on broad classifications.

Considering the inherent variability in naturally occuring materials, better definitions of rock types are needed to give a clearer idea of the expected performance. An experienced petrographer can be very valuable in determining a particular rock type and the associated predominant minerals. He may also be able to provide valuable information regarding the quality of a particular ballast material.

2.2 Gradation

There is considerable debate, but very little field evidence, concerning the performance benefits of various ballast gradations. The relatively "narrow" grading currently used is the accepted standard for North American railroads; AREA Gradations #3, #4, and #5 all fit this description, but have different maximum particle sizes (see Figure 3). However, research indicates that a broadly graded ballast may reduce the amount of cumulative deformation under load, and limit fouling from the subgrade or from transported materials, since the voids are smaller. In 1958, Chamberlin and Yoder studied the effects of grain-size distribution on cumulative deformation and intrusion of soil into highway base coarse gravel [4]. The control parameter for gradation was the "n" in the equation:

$$\%P = (d/D)^n \times 100\%$$

where P is the percent passing a given sieve mesh, d is the

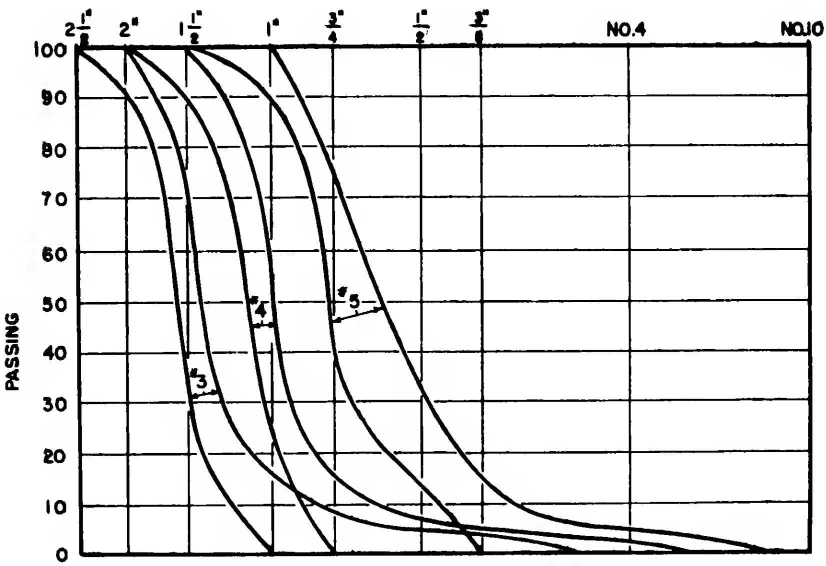


Figure 3. AREA Gradations No. 3, 4 and 5.

sieve size, D is the maximum particle size and n indicates, with increasing values, a decreasing range of particle sizes. From this study, an "n" value of approximately 1.0 appears to be optimum with respect to cumulative deformation, as shown in Figure 4. Subgrade intrusion increased for n values greater than 1.2, but leveled off below this value. To provide a frame of reference, AREA gradations #3, #4 and #5 have "n" values of approximately 2.5.

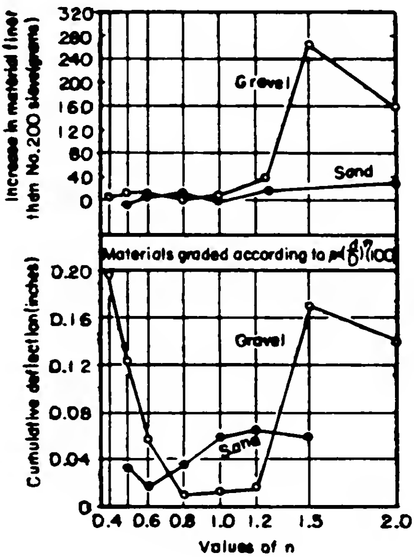


Figure 4. Effect of Grain-size Distribution on Preventing Subgrade Intrusion During Repeated Loading Tests.

Raymond, et al. once recommended a gradation which has an "n" of about 1.0 [5] (Figure 5). Under repeated loads, triaxial tests of three of the four ballast materials showed less cumulative permanent strain for the broad-graded samples, as

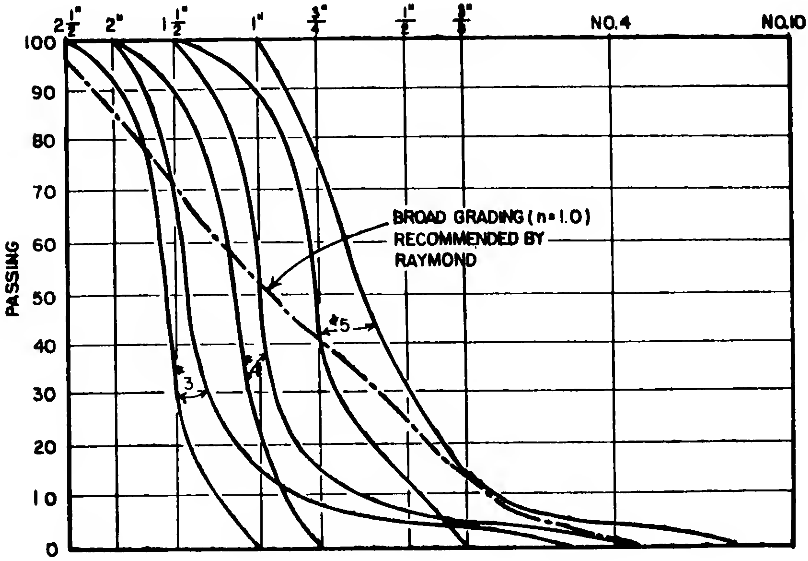


Figure 5. AREA Gradations and Raymond's Recommended Gradation.

compared to large and small single-sized samples of the same material. In another study Gaskin et al. subjected ballasts of "n" values = 0.3, 0.5, 0.7, 1.0, 1.5 and 2.0 to vibratory compaction and monitored the increase in density [6]. The results are shown in Figure 6 and indicate that an optimum value appears to exist for n in the range from 0.7 to 1.0. Since the strength of a granular mass is very sensitive to its density, and density changes with "n" value, these findings indicate that a more broadly graded ballast would perform better.

Ease and effectiveness of maintenance tamping is another ballast performance factor which would also seem to be affected by the ballast gradation. The larger the average particle size, the less ballast particles will be pushed under a tie during maintenance tamping.

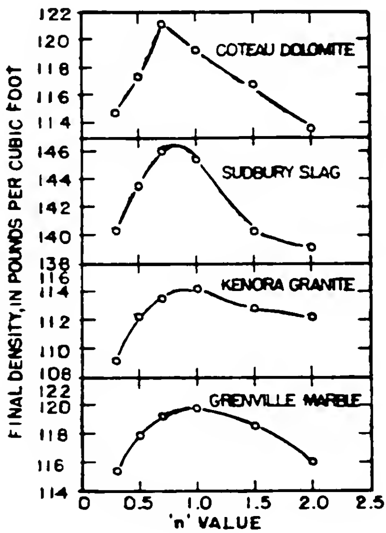


Figure 6. Final Density Versus "n" Values with a Peak Acceleration of 3.5 g.

Johnson showed that tamping raises, which are smaller than the average ballast particle size, quickly return to their pre-tamped elevation, whereas larger track raises remain for a longer period of time [7]. The maximum particle size would be of importance, since the particles would not move easily under a tie when a tamper tine is applied.

Drainage of a broad-graded ballast is another consideration. The lesser volume of voids in a broad-graded ballast may foul more quickly as a result of ballast degradation. Recognizing this, Raymond proposed that permeability tests be performed on the fines generated from a laboratory impact or abrasion test [5]. Raymond has recommended acceptance of the ballast if the coefficient of permeability of the fines is greater than 1.0 micrometer/sec, because the fines would then be coarse enough and drainage would be not be impeded. Clogging of the voids is a valid concern, if the source of fouling material is internal, that is, due to ballast wear. However, a broad grading may help to keep foreign contaminants out, because it acts like a filter. Perhaps the greater permeability of the narrow-graded ballasts is actually detrimental to the track structure, because rain water and surface infiltration have greater access to the subgrade. In fact, the members of AREA Committee 1 once pondered the deliberate filling of ballast voids with sand to keep the water from flowing immediately to the subgrade [8]. The water in the sand would be held by capillary action and evaporate during dry weather.

Without actual field test results, the optimum ballast gradation with respect to permeability, ease of maintenance and resistance to permanent strain cannot be confirmed. The benefits indicated in laboratory experiments must be proven under actual field conditions. Even so, field test sites introduce new variables not present in the controlled laboratory system. For example, control over the placed gradation is lacking when it is dumped from a hopper car. The broader the gradation, the more likely particle size segregation will occur during the transporting and placing of the ballast. Since cumulative deflection of a ballast is strongly dependent on its bulk density, the variation of gradation along the track may result in "built-in" differences in track settlement. This differential settlement due to non-homogeneous gradation may mask the improvement in track stability gained from the greater overall density of the broader-graded ballast. Only a well designed and controlled field test can determine the maintenance costs and benefits of various ballast gradations.

2.3 Maximum Particle Size

Some studies report an increase in ballast strength with increasing maximum particle size, while others report no significant improvement. The mixed results may stem from a tradeoff involving breakage of the larger particles (particularly if they are elongated or flat) and increased bulk density, due to a broader gradation. Selig found that, in his ballast box experiments, the largest ballast particles tended to fracture early in the test, producing a noticeable settlement. Although these large sized particles are few in number, they can greatly affect settlement.

Perhaps more important is the effect of maximum particle size upon maintenance tamping. As stated previously, tamping of coarse ballast particles may result in too few particles supporting the tie. The limiting maximum size of ballast may well depend on maintenance effectiveness. This upper limit on size has not yet been quantified.

2.4 Density

Bulk density of an aggregate is a function of two factors: particle density or specific gravity, and interparticle void content. Taken separately, the void content is highly related to gradation and compactive effort. The particle specific gravity is an intrinsic property of the ballast material and is not controllable. An increase in bulk density from either broader gradation or denser particles will improve ballast stability. Since no control is exercised over the void content of the placed ballast, however, the density of the ballast under one tie may differ significantly from that under the next tie, due to changes in gradation and/or compactive effort.

The specific gravity of ballast particles may ultimately be of secondary importance to track stability, especially since the value does not vary greatly, e.g., between 2.5 and 2.8 for most ballast material types, although slag can have a value greater than 3.0.

2.5 Shape

Ballast particle shape can have a large effect on ballast layer stability by contributing to the "interlock" of the particles. Interlock is a general term used to describe the resistance of the ballast to movement under load. While the growth of sliding point contacts between particles under load and vibration can be more pronounced with rounded particles, angular or cubical ballast will resist movement better. This occurs because the rocks around a particular angular rock must move in order to allow this rock to move. As angularity increases, so does the dilation required for particle movement. The more angular a ballast particle, the more dilation of nearby rocks is required for its movement, hence the increased resistance to ballast layer deformation.

The effects of ballast shape and angularity upon track stability are not well documented. In one such attempt, Gaskin and Raymond have correlated a field stability rating to sphericity, elongation index, flakiness index and roundness test results, for ten in-service ballasts [9]. The coefficient of correlation for these tests were 53%, 43%, 14% and 0%, respectively.

Because some degree of correlation appears to exist between field stability and elongation, Raymond proposed an upper limit of 10% to Elongation Index test results [5]. Also, results from the FAST Ballast II experiments indicated a ballast which had a number of elongated (but not flaky) particles performed better than those ballasts which did not have an abundance of such shapes.

Some sort of "dowel action" may be imparted to the ballast layer by virtue of these ballast shapes. This is a very tentative finding and should be examined carefully. (This finding is also clouded by confusion between the definitions of flaky and elongated.)

However, before any such limits can be placed on tests which measure particle shape, two fundamental problems must be dealt with:

1. The need for a quantitative definition for acceptable shapes of individual ballast particles.
2. The determination of the allowable or recommended percentage (by weight) of ballast particles having these shapes, as determined above, within a given ballast mass.

Raymond recommends allowable shape factors of 2.0 to 2.75, 2.0 being the value for the best track class (a perfect cube has a shape factor of 1.73). The AREA Manual specifies that flat or elongated particles, i.e., those that have length to average thickness ratios greater than or equal to 5, be limited to 5% by weight. No distinction is made between flat and elongated in the manual. Unfortunately, these guidelines are based on subjective evidence of ballast behavior, rather than from actual tests on material response to loading, and no practical means of measuring these values has yet been developed.

Laboratory testing of ballast with various quantities of flat/elongated particles is required.
Such tests would involve compaction and cyclic loading triaxial tests to determine the effects of particle shape upon the increase in ballast bulk density and stability under load.

Of the tests used to characterize particle shape, Huang has developed a Particle on Index Test as a measure of shape, angularity and surface texture of aggregate particles [10]. These geometric characteristics of fractured rock may then be related to ballast cumulative deformation and responsiveness to maintenance tamping. In testing the resilient modulus of various ballasts at different gradations, Thompson has shown that the particle index and resilient modulus test results appear to be related, although the relationship is inconsistent [11].

The repeatability of the shape factor test is questionable, since this test requires measurement of "the largest dimension divided by the smallest." Although a measurement of this kind seems to be straightforward, there is a source of much variability between technicians, since the ballast particles do not have well defined geometric shapes. The Particle Index Test is fairly repeatable, however, and gives a measure based on a number of particles acting together, rather than single particles measured one by one manually. The Particle Index Test may be worthy of further investigation.

The British Standard Tests include Elongation and Flakiness Tests, which are also worthy of consideration. Ballast particles are passed through a flakiness gauge and an elongation gauge, respectively.

Measurement bias would probably be less with this method than with a procedure where direct measurement of the particle is needed. Also, the test description for the British method includes the ballast particles of maximum size in the measurement, whereas the Shape Factor Test specifies only those particles which are 50% to 70% passing on a gradation chart. However, the particle sizes which are most often the flakiest are the larger ones, e.g., particles sizes corresponding to 80% to 100% passing. Even though these larger particles may be few in number, they can greatly effect settlement of a tie by virtue of their size, if they fracture under load.

The Shape Factor, Elongation and Flakiness Tests draw a distinction between elongated and flat particles (unlike the AREA specification). This may be important since, as mentioned, a limited number of elongated particles may actually be beneficial to track stability.

2.6 Hardness and Toughness

Hardness of a material is its resistance to abrasion. Toughness is the resistance to fracture under impact loads. The distinction between these two rock properties is important, since they imply field breakdown from two separate causes. Tests that are presently in use, which primarily characterize hardness, are the Mill Abrasion (MA), Deval Attrition and Scratch Hardness Tests. Toughness tests include the Crushing Value and Los Angeles Abrasion (LAA) Tests.
Despite its name, the LAA test is more of a test of fracture toughness than abrasion, since it involves steel balls impacting the ballast material. Some abrasion is undoubtedly involved, as the particles are rolling over one another as the drum rotates, but this is secondary to the impact loadings. Although it is an AREA-recommended test, the LAA method has fallen out of favor with many practitioners. Studies have shown [12] that the results of LAA tests correlate poorly, or perhaps not at all, with field performance, as shown by the scatter of the data in Figure 7.

A tradeoff between hardness and toughness often exists where a material that performs well in the MA test may fall apart in the LAA test, and vice versa. Raymond has found that rocks which are soft but strong, or hard but weak, need both tests to characterize this tradeoff [5]. The two index tests, MA and LAA, should be used to characterize the distinct properties of hardness and toughness of ballast. CP Rail has adopted Raymond's approach in using the LAA results to test toughness and the MA to test hardness. The equation below, as used in the CP Ballast Specification [13], provides a measure of quality and is based on both parameters:

$$\text{Abrasion Number} = \text{LAA} + 5(\text{MA})$$

The MA number is multiplied by 5 to give it equal numerical weighting to the LAA result, since both are judged to be equally important in the performance of ballast. The Abrasion Number is then used to predict when ballast should be maintained or replaced, based on the original gradation of each ballast.

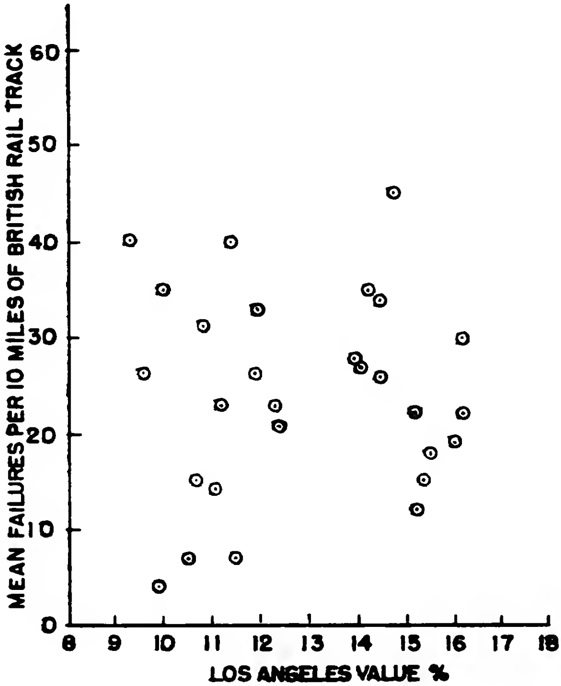
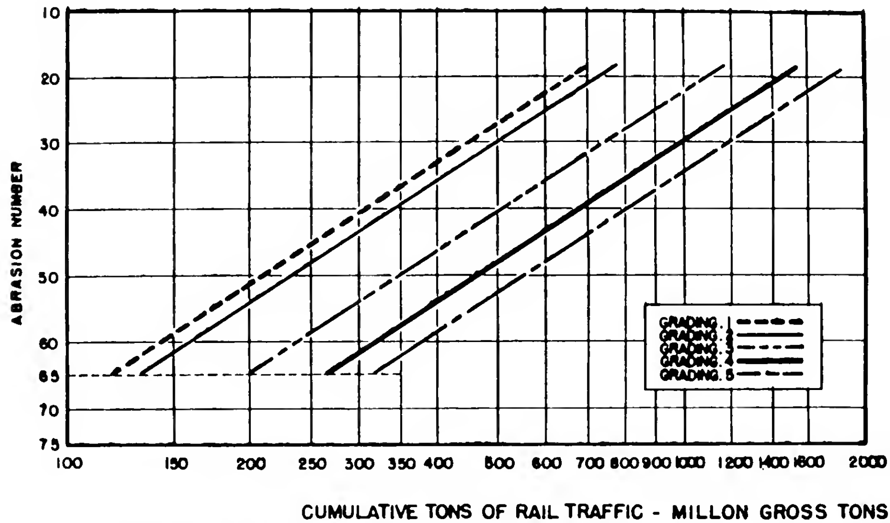


Figure 7. Relationship Between Ballast Failures and Los Angeles Abrasion Value.

The criterion for maintenance is the point at which the voids would be filled with broken and abraded material, as indicated by the Abrasion Number (see Figure 8).

The importance of Figure 8 is that it represents a link between ballast specification tests and field performance, a link that has not been established by any other specification tests. Although this method of determining ballast maintenance life is somewhat of a simplification, since the assumed amount of fouling material from external sources is arbitrarily



NOTE: DEVELOPED FOR TANGENT TRACK WITH 7 IN. OF BALLAST BELOW TIE. A SMALL AMOUNT OF CONTAMINATION FROM OUTSIDE SOURCES HAS BEEN TAKEN INTO CONSIDERATION.

CAUTION: EXCESSIVE HANDLING OF BALLAST MATERIALS IN THE UPPER RANGE OF ABRASION NUMBERS MAY GENERATE FINES WHICH WILL REDUCE THE APPLICABLE CUMULATIVE TONS OF RAIL TRAFFIC.

Figure 8. Ballast Abrasion Number Versus Cumulative Tons of Rail Traffic, for Various Ballast Gradations.

selected as 10%, it remains an important step toward realistic field performance tests.

2.7 Angle of Internal Friction

Friction is very important to the stability of a fractured rock mass. Slopes and tunnels cut in heavily jointed rock may be stable, simply because of this property. Since the stress fields in track are largely compressive, the friction that develops between ballast particle contacts is essential to track stability. An outward manifestation of this friction in a granular material is the so-called angle of internal friction, ϕ , as determined from the slope of the failure envelope of Mohr circles based on triaxial shear tests (see Figure 9a). The ϕ is

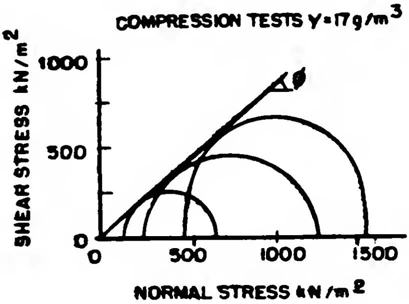


Figure 9 (a). Mohr Circles and Failure Envelope from Typical Compression Tests of Granular Materials.

also exhibited by the angle of repose of the loose material, although this ϕ value may be different from that obtained from the triaxial tests, since it is very dependent upon confining stress, especially at low values of confining stress.

The ϕ is really a composite effect of many ballast properties. The ϕ angle is primarily a function of ballast gradation, particle shape, angularity, surface texture and grain size. It is difficult to assess to what extent each contributes to the value.

Some researchers discount the relevance of the ϕ to field performance, while others hold that it is an indirect measure of particle interlock. Raymond found that plots of Mohr's circles from compression tests on different ballasts had failure envelopes with a non-zero intercept [14]. This is equivalent to saying that ballast exhibits apparent cohesion, since there appears to be a small amount of shear strength when the confining stress is zero. Raymond attributed this to particle dilation, changing friction angle and particle interlock, with interlock probably being the major factor. However, since the angle increases dramatically at low confining stresses (see Figure 9b), the envelope may go through the origin rather than intercept the Y-axis. Since triaxial testing is not usually performed under these very low lateral stress conditions, the

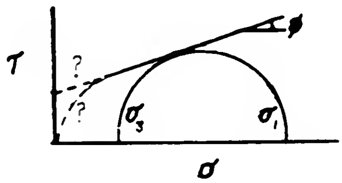


Figure 9 (b). Failure Envelope Y-axis Intercept.

appearance of an intercept may be due to the tendency to extrapolate a straight line beyond where the data ends.

Selig's ballast box [2] may be measuring the equivalent of when the side-pressure transducers register ratios of residual lateral pressures as great as 14 times the static overburden. The residual stress in a ballast may be a direct measure of the ability of a ballast to maintain track geometry.

Although one normally thinks of residual stresses as existing in cohesive materials, a granular material may also exhibit a certain amount of residual stress. If these stresses are relieved through vibration under loading, movement of the ballast layer will possibly result. British Rail researchers have found that some sites which require a large amount of maintenance have ballast that is rotating laterally on a thin layer of clay [12]. While this may be primarily a subgrade failure, the loss of interlock between ballast particles through vibration and resilient subgrade movement could also be a cause. Raymond has also found that ballast often moves outward over a soft subgrade.

The residual stress and its importance to ballast stability is being investigated further by Selig. Selig is also investigating the possible existence of gross tensile stresses in the ballast layer. If these tensile stresses exist (as predicted by computer models), this could explain the ballast failures of the type observed by both British Rail and Raymond, since the residual stress would be exceeded by the tensile stress.

While the exact nature of ϕ and its relationship to tensile and residual stresses is somewhat undefined, it may provide a useful index of ballast particle interlock and, hence, stability under loading. The best method of measurement may not be the arduous and time-consuming process of triaxial shear tests, as performed by Raymond, but rather some simpler method, such as measuring the unconfined natural slope of the ballast particles.

2.8 Weathering Resistance

Weathering of rock occurs as a result of two processes: mechanical and chemical. Mechanical weathering involves breakdown through continued freeze-thaw cycles. Chemical weathering is the change in mineral composition by chemical attack. Certain constituents of rock are more susceptible to alteration than others, e.g., feldspars dissolve to form the clay mineral kaolinits and carbonate minerals (as in limestone and dolomite) are water soluble. Quartz, on the other hand, weathers very little.

Knowledge of the mineral composition of a material will give qualitative information regarding its weathering resistance. However, very little can be said about the rate at which a material will weather. Such predictions would require knowledge of the climate and conditions at the site at which the ballast will be placed, something that is not often known before hand.

The tests currently used to measure the susceptibility of a rock to breakdown through mechanical weathering are Freeze-thaw Tests, Sodium or Magnesium Sulfate Soundness Tests (SSS or MSS), and absorption tests. Raymond found that the results of SSS tests and the field breakdown ratings of ballasts were highly correlated [5]. The SSS test is currently included in the AREA Manual. The Canadian Pacific and Canadian National have both included this test in their ballast specifications.

When subjected to freezing temperatures, ballast may also be susceptible to degradation.

When water freezes, it expands by about nine percent and exerts splitting forces on the very outer interstices of the ballast particles. The resulting degradation depends upon the strength of the minerals and their bonds in the matrix. Some researchers state that the Absorption test adds little to the SSS, MSS or Freeze-Thaw test results, and therefore only one of the latter tests need to be performed. However, the absorption percentage indicates how much water has access to the internal structure and thus gives extra weight to a weathering loss test result. In research by Raymond, it was seen that a low freeze-thaw or SSS loss for a ballast material does not necessarily mean that it will not weather excessively in the field [9]. In one case, a ballast with a low F-T loss and high absorption value was seen to degrade excessively in the field and produce an extremely muddy ballast.

Dalton discovered that an approximate relationship exists between F-T loss and % Absorption for the ten ballasts he studied [15]. However, only one ballast had a relatively high value for both tests and there were no data points in the mid-range. Therefore, the correlation was only tentative (see Figure 10).

Unfortunately, there are no tests for degradation due to chemical weathering. Little is known about the weathering characteristics of ballast, although a petrographer can make some educated guesses concerning which minerals are more prone to weathering in a given environment.

2.9 Ballast Field Performance and Laboratory Results

In a comparison of laboratory test results with field performance, Gaskin and Raymond studied ten ballast materials which are in use on the Canadian National Railways [9]. Raymond characterized their field performance by two different, somewhat subjective, rating systems of (1) field breakdown and (2) stability rating. One finding was that the abrasion number correlated fairly well with observed field breakdown and

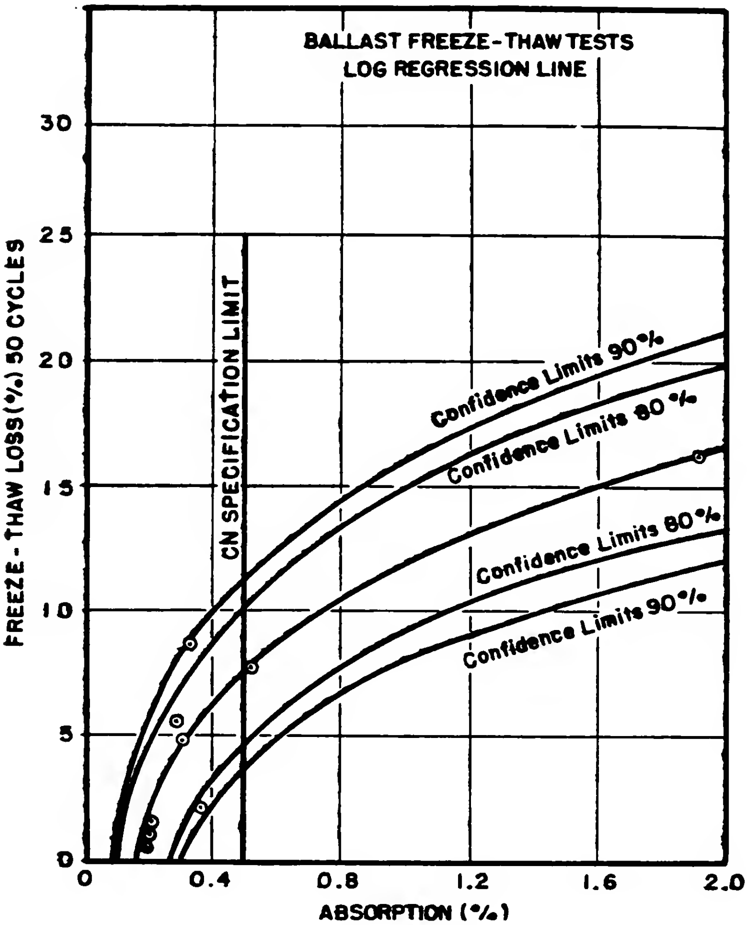


Figure 10. Percentage of Absorption Versus Percentage of Freeze-thaw Loss During Fifty Cycles.

stability. As Figure 11 shows, the abrasion number follows predictable trends for the various ballast material types.

This report noted that no one test is sufficient to judge the overall quality of a ballast. When one considers the mechanisms of breakdown and separates them into their components, each of the strength parameters can be judged independently of one another. This is the idea behind the Abrasion Number, which characterizes two different strength parameters.

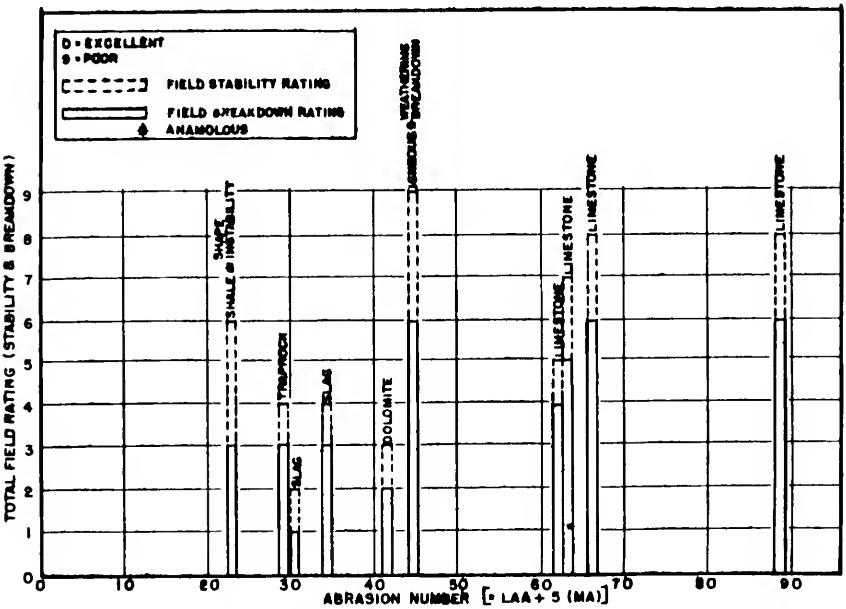


Figure 11. Abrasion Number Versus Total Field Rating.

A comprehensive ballast specification must include a minimum number of tests of all of the relevant ballast properties that affect track stability, without including tests that assess the same properties, but by means of slightly different procedures. Such a performance specification could be developed from field investigations which assess the in-track performance. For the appropriate characteristics, one could then assign numbers to the various ballast strength parameters in weighted proportions to their effects upon track performance.

To assign such numbers, one must know much more than is currently known about how various ballasts perform in track and how their characteristics affect track behavior. In Gaskin and Raymond's research, where such an assessment was attempted, the subjective classification system yielded significant findings. The field ratings were broken down into two groups, as previously discussed. The field breakdown rating was based on the observed fines and chips of broken ballast particles and any evidence of pumping. The field stability rating indicated the extent to which the ballast was a maintenance problem. The distinction between these two is significant, since a ballast may breakdown very little, and yet require much maintenance, and vice versa.

This distinction is best illustrated in the case of shale ballast (Figure 11), which has the lowest values of LAA or MA breakdown, and, correspondingly, shows little breakdown in the field. However, the shale requires considerable maintenance to retain line and surface. This may be due to the effect of particle shape upon the overall track stability, since the shale particles had the highest particle index (i.e., were flaky), but a contributing factor may also be that shales are especially prone to strength loss due to weathering and can fracture.

The igneous ballast shown in Figure 11 was very muddy in the field and did not respond to maintenance. Therefore, this ballast received the lowest field ratings for both breakdown and stability (6 and 3, respectively). This poor performance was predicted only by the tests of weathering resistance: the Absorption and Magnesium Sulfate Soundness Tests.

It is clear that while the abrasion number may account for the majority of ballast performance problems, there are instances where other mechanisms of breakdown predominate. The high absorption value for the igneous ballast may indicate a propensity to weather more deeply than other ballast materials. It is clear that other mechanisms for instability may greatly overshadow the resistance of a ballast to abrasion or impact, since, in the case of shale, it ranked the best in terms of abrasion number and yet had one of the worst field stability ratings.

It appears that, by selecting certain tests and excluding others, the risk of not considering a potentially important parameter of ballast quality (which may have large economic consequences if the ballast does "fail") is great. It is necessary to consider enough properties of the ballast material, so that the probability of not screening out an undesirable ballast material is acceptably low. To take the Raymond study as an example, the field performance of eight of the ten ballast materials were predicted reasonably well by only the LAA and MA tests. The 80% success rate for this study is fairly good. To attain a 100% success rate, weathering and shape factors would also probably have to be considered for the materials in this study.

There will always be "outliers" from the predicted performance, since ballast properties are highly variable and one thus runs the risk of ignoring some breakdown potential. However, if the four basic parameters of abrasion, fracture resistance, weathering and particle shape are tested with better test methods, then the probability of this occurring becomes relatively small.

3.0 ORIGIN OF FOULING MATERIALS

Central to any field evaluation of ballast performance is the question of the origin of the fines found in the ballast voids. If the fines are predominantly generated by ballast breakage and abrasion, then the ballast can be said to be failing. However, other sources, such as windblown sand and silt, contaminants from traffic and subgrade intrusion may combine to foul a ballast long before weathering or traffic loadings can cause a significant amount of ballast degradation. The CP Rail Ballast Specification considers that 90% of the fouling is due to internal abrasion and breakage, while the remaining 10% is from external sources. From work performed by Selig with his ballast box, such a large accumulation of fines does not appear to be generated internally, since, under simulated traffic loading, the accumulation of fines starts out small and increases relatively little throughout the test [2]. Perhaps the simulated loading is not severe enough, because it does not include the vibratory actions and impacts of actual train loadings. In any case, there is disagreement between researchers as to the most prevalent source of fouling.

To determine if ballast failure is really the main cause of a heavily fouled ballast section, one must analyze the fines. Little research has been performed in this area, but there are a few tests methods, both simple and complex, that provide some indications. The simplest method is to test the fines for their Atterberg Limits [16]. If the moisture contents at the Atterberg limits are about the same as for the clayey subgrade, then subgrade fouling may be indicated. One has some justification to say this, since fines from ballast abrasion are usually low in clay-size particles and thus would not exhibit very great plastic properties. However, if the fines are not as plastic as the subgrade, they could also be deposited from above the track and not necessarily result from ballast degradation.

A test which provides more information on the character of the fouling material is the Methylene Blue Absorption Test recommended by the ORE [17]. In this test, the fouling material is mixed with methylene blue dye and the amount of dye added to attain a reference condition of saturation is noted. The higher the value, the more clayey are the fines and the more water retention capability it has. This value can be compared to that of the subgrade to judge if the source of fouling is from the subgrade. Once again, this test can indicate if subgrade intrusion is to blame, but it does not differentiate between internal fouling and materials deposited from above the track.

A chemical analysis of the fines is significantly more complex, and requires a chemist or a skilled technician. The results, however, provide better information, since the chemical nature of the fouling fines can be compared to fines generated from the ballast in a laboratory abrasion or impact test. If the fines are very similar, then internal abrasion may be the major source.

A still more advanced approach is to use x-ray diffraction or scanning electron microscopy to determine the elements and minerals present. A petrographer can then look for similarities in a thin section rock specimen.

Organic matter, such as coal fines and wood chips from ties, can be detected by the weight loss on ignition.

4.0 CONCLUSIONS AND SUGGESTED RESEARCH

The comprehensive Ballast and Subgrade Requirement Study by Simon, et al. notes that "...railroad ballast is the most severe application of earth material aggregates in civil engineering, in terms of applied stress levels and environmental exposure" [18]. In spite of this, little work has been done in North America to study ballast behavior (with the exception of Raymond, Thompson and Selig). Most of the research on ballast has been, and continues to be, performed by foreign organizations such as ORE and British Rail. We may draw on the experience of these organizations, but the heavier axle loads prevalent in this country must also be considered.

The difference of opinion between individual railroads and the AREA Manual concerning the relative importance of ballast parameters is obvious by the emphasis on different tests and limiting test values, although some of this difference can be ascribed to changing environments and track quality standards. Appendices A and B show this divergence in the tables of ballast tests, recommended limiting values contained in the AREA Manual [19], and those being used by certain railroads.

Studies by Gaskin and Raymond have isolated certain parameters that appear to be more important than others in determining the performance of ballast [9]. They are: (1) hardness, (2) toughness, (3) shape and (4) weathering resistance. Raymond recommends that any testing for quality be directed toward these properties. However, many of the basics of ballast research have not yet been sufficiently addressed, e.g., grading.

The following topics are recommended for further investigation:

1. Determine cause(s) of ballast fouling, origin of fines and amount of ballast particle wear.

2. Determine mechanisms of ballast movement in track, using probes inserted into the track structure and by full-scale tests in the laboratory.

3. Study vibration effects on ballast degradation and movement.

4. Determine if optimum grading exists, by the use of in-service and laboratory tests.

5. Determine if chemical weathering is significant, e.g., "acid rain effects."

6. Determine effects of particle shape upon ballast stability; develop tests to characterize them and establish limits on certain particle shapes.

Perhaps the largest contribution to be made to the study of better ballast selection would be a field investigation of sites where ballast has failed, such as performed by Gaskin and Raymond [9]. This, together with monitoring of in-service tests and full-scale laboratory tests, should provide many of the answers to the topics listed above.

5.0 REFERENCES

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6.0 APPENDICES

6.A Appendix A
American Railway Engineering Association Ballast Specifications

6.B Appendix B
Selected Railroad Ballast Specifications

6.A Appendix A

AMERICAN RAILWAY ENGINEERING ASSOCIATION
BALLAST SPECIFICATIONS

Property	ATSM Designation	Limits (Weight %)
ear L.A. Abrasion)	C131 or C535	Maximum 40% Loss
oundness	C88 (Sodium Sulphate Solution)	Maximum 7.0% Loss after 5 cycles
oft and riable Pieces	C235	Maximum 5.0%
aterial Passing 200 Sieve	C117	Maximum 1.0%
lay Lumps	C142	Maximum 0.5%
longated or hin Particles	By Visual Inspection	Maximum 5.0%
ulk Unit eight	C29	Min. 70 lb per cu ft blast furnace slag Min. 100 lb per cu ft steel furnace slag

6.B Appendix B

Selected Railroad Ballast Specifications

Atchison, Topeka and Santa Fe Railway

Property	ATSM Designation	Limits (Weight %)
Wear (L.A. Abrasion)	C535	Maximum 30% Loss
Soundness	C88 (Sodium Sulphate Solution)	Maximum 3.0% Loss after 5 cycles
Soft and Friable Pieces	C235	Maximum 0.5%
Absorption	C127	Maximum 1.5%
Clay Lumps	C142	Maximum 0.5%
Cementing Value	N.A.	Maximum 250 psi.
Bulk Unit Weight	C29	Minimum 90 lb per cu ft

Canadian Pacific Limited - Primary Track (CWR)

Property	ASTM Designation	Limits (Weight %)
Specific Gravity	C127 (Saturated Surface Dry Basis)	Minimum 2.60
Wear (L.A. Abrasion)	C535	Maximum 45% Loss
Soundness	C88 (Magnesium Sulphate Solution)	Maximum 1.0% Loss after 5 cycles
Absorption	C127	Maximum 0.5%
Mill Abrasion	N.A.	Maximum 9%
Abrasion Number	N.A.	Maximum 65%

Consolidated Rail Corporation - Class "A" Track

Property	ASTM Designation	Limits (Weight %)
Wear (L.A. Abrasion)	C131	Maximum 10% Loss
Soundness	C88 (Sodium Sulphate Solution)	Maximum 0.5% Loss after 5 cycles
Soft and Friable Pieces	C235	Maximum 5.0%
Material Passing #200 Sieve	C117	Maximum 0.5%
Clay Lumps	C142	Maximum 0.5%
Impedance	N.A.	Minimum 2600 ohms

Illinois Central Gulf Railroad - Main Line Track

	Property	ATSM Designation	Limits (Weight %)
CRUSHED SLAG	Specific Gravity	C127 (Saturated Surface Dry Basis)	Minimum 2.23
	Wear (L.A. Abrasion)	C131	Maximum 40% Loss
	Soundness	C88 (Sodium Sulphate Solution)	Maximum 10% Loss after 5 cycles
	Soft and Friable Pieces	C235	Maximum 5%
	Material Passing #200 Sieve	C117	Maximum 1%
	Clay Lumps	C142	Maximum 0.5%
CRUSHED LIME-STONE	Specific Gravity	C127 (Saturated Surface Dry Basis)	Minimum 2.67
	Wear (L.A. Abrasion)	C131	Maximum 40% Loss
	Soundness	C88 (Sodium Sulphate Solution)	Maximum 10% Loss after 5 cycles
	Soft and Friable Pieces	C235	Maximum 5%
	Material Passing #200 Sieve	C117	Maximum 1%
	Clay Lumps	C142	Maximum 0.5%

Norfolk Southern Corporation

	Property	ATSM Designation	Limits (Weight %)
GRANITE and LIME-STONE	Wear (L.A. Abrasion)	C131	Maximum 35% Loss
	Soundness	C88 (Sodium Sulphate Solution)	Maximum 2.5% Loss after 5 cycles
	Soft and Friable Pieces	C235	Maximum 0.5%
	Material Passing #200 Sieve	C117	Maximum 0.2%
	Clay Lumps	C142	Maximum 0.2%
	Cementing Value	N.A.	Maximum 200 psi

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COMMITTEE 13—ENVIRONMENTAL ENGINEERING

Report of Subcommittee No. 1

Leaking Underground Storage Tank (LUST)

40 CFR 280, July 15, 1985
Regulation Summary

M.J. Boyer (Subcommittee Chairman), L.W. Pepple (Vice Chairman), L.B. Boyd, C.A. Culley, J.J. Dwyer, J.M. Gennette, C.W. Harmon, Jr., R.R. Holmes, S.F. Linhardt, R.T. Noonan

I. Introduction

Leakage from underground storage tanks has become a major health and environmental concern for both industry and government. A recent Congressional study of leaking tanks reported that of 2,000,000 underground tanks in the United States containing hazardous substances or gasoline, an estimated 100,000 (5%) currently are leaking, and an additional 350,000 (17%) are expected to leak in the next five years.

In November 1984, President Reagan signed into law the Hazardous and Solid Waste Amendment of 1984, amending the Resource Conservation and Recovery Act (RCRA). Included in the Amendments is a new Title VI which creates a regulatory program governing underground tanks used for the storage of regulated substances.

"Regulated substances", for the purposes of the Leaking Underground Storage Tanks (LUST) program, means petroleum products and "hazardous substances" as defined under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA or Superfund), with the exception of any substance regulated as a hazardous waste under Subtitle C of RCRA. This definition is much broader than hazardous wastes and includes diesel fuel, gasoline and other oils and solvents commonly used in rail yard and shop areas.

Congress has defined an underground storage tank as:

> Any one or combination of tanks (including underground pipes connected thereto) which is used to contain an accumulation of regulated substances, and the volume of (including the volume of the underground pipes connected thereto) is 10 per centum or more beneath the surface of the ground.

Excluded from the definition of regulated tanks are farm and residential tanks of limited capacity used for motor fuel and home heating fuel, most wastewater separators and collection systems, and certain other tanks not used for the storage of regulated substances. Despite the numerous exceptions, the definition remains remarkably broad, and could encompass many tanks not considered by the owners as "underground".

The majority of underground storage tanks, in fact all but a very small number, contain raw materials—products which are an integral part of a manufacturing facility. It is likely that most of the leaks from these tanks are small. If a leak were major, the owner probably would lose sufficient raw material to impact production, and would take remedial action. It is precisely the small leaks of highly mobile solvents and petroleum products that the RCRA amendments seek to control.

A number of states are adopting similar underground regulations, some of which may be more stringent than the federal law. This summary does not address these state laws, however it is recommended that the individual roads check the states in which they operate.

II. Requirements

There are a number of provisions which require action in the near future by owners of tanks. Other sections of the regulations are now being developed by EPA.

9002*Notification - EPA has published the forms and instructions of notification. All owners of underground tanks in operation or taken out of operation (but not removed) prior to January, 1974 must file notifications by May 8, 1986. Copies of the forms are available from EPA and state offices. As a practical matter, owners should be inventorying and testing underground tanks (and consider removal) at this time.

Other sections of LUST regulations require suppliers of regulated substances and tank installers to notify the recipients of these products.

9003 Interim Prohibitions - Between May 7, 1985 and EPA development of new tank standards, regulations essentially prevent installation of new buried tanks which are of a design that cannot guarantee leak prevention throughout the life of the tank.

9003 Technical Standards - EPA is currently developing standards for new buried tanks. These standards must be in place by May, 1987 for petroleum tanks and November, 1987 for other substances.

9003 Financial Responsibilities - EPA is developing standards requiring financial responsibility for environmental damages caused by leaking tanks. This may be through self insurance or outside coverage.

9003 Corrective Action - EPA is developing regulations addressing required corrective actions applicable to future leaking underground tanks. Past problems are covered under superfund, from a regulatory viewpoint.

9004 State program approval - EPA intends for the LUST program to be implemented at the state level.

9006 Inspection and Enforcement - Self-explanatory, regulations being developed by EPA at this time.

It is highly recommended that the reader research major provisions of the regulations in greater depth if applicable.

*Refers to Federal Regulation Number

COMMITTEE 34 — SCALES

Innovations in Railroad Weighing
Report Of Kilowate Track Scale Tests

With the concurrence of the Chief Engineer of the Georgetown Railroad Company, a special committee of AREA Committee 34 met in Georgetown, Texas, on February 26, 1985, for the purpose of conducting a test of the Kilowate Track Scale on the Georgetown Railroad. Members of the committee present were:

C.T. Picton - Vice Chairman Committee 34 and Chairman Special Committee

F. J. Loyd, Jr.	J. R. Kaberline
G. L. Schenck, III	W. G. Gemeiner
R. T. Taylor, Jr.	L. W. Carroll
D. E. Keefer	E. F. Paschal, Jr.

The Georgetown Railroad and Kilowate Inc., were represented by various individuals throughout the testing. They were:

Ned Snead	Gary Brinkley
Sherron Snead	Bob Fischer
Charles Turner	Bill Parrish
Mark Dixon	Larry Ray
Lenard Steglich	

The Missouri Pacific Railroad was represented by T. R. Loyd, for the purpose of testing the static reference scale with Missouri Pacific Railroad's MPX-194 Test Car.

1. DESCRIPTION OF SCALES

Reference Scale

Location:	Georgetown Railroad, Georgetown, Texas
Type:	Webb, Four Section Lever
Length:	60 feet
Capacity:	300,000 pounds
Indicator:	Toledo 8132 electronic digital indicator attached to 1K load cell in steelyard rod.

Kilowate Track Scale

Location:	Georgetown Railroad, Georgetown, Texas
Trade Name:	"Train-Wate"
Type:	Kilowate, Coupled-in-Motion Axle Weigher
Length:	7 feet 8 inches (5 feet 4 inches clear span)
Description:	The bridge consists of two 7-foot 8-inch sections of 115 RE rail placed in the track adjacent to each other and attached to track with bolted joint bars. Ties are spaced to provide an open span for 5'4" under the rails. Each rail has four strain gages attached to the base of the rail. Temperature variations were compensated for by the computer. Two timber stringers, 8"x16"x28'0", were placed to support nine ties on each side of the scale. The stringers were placed one under each rail, parallel to the rail, with the 16-inch side of the timber against the bottom of the ties.
Capacity:	75,000-lb/axle (varies with rail section and span length).
Indicator:	IBM Personal Computer with printer.
History:	Installed January, 1984. Scale has been used for experimental weighing for the purpose of scale testing and calibration, weighing an average of 1,000 cars per week. In addition, all outbound trains pass over the scale without being weighed. This traffic averages 480 cars per week.

Track Condition and Geometry:

1. Ballast and Subgrade - excellent condition and well drained.
2. Surface - excellent throughout tangent.
3. Alignment - track is tangent from about 600 feet north of scale to 700 feet south of scale, with excellent alignment.
4. Grade - ±0.4% descending to the north.
5. 56-¼ to 56-½ inches in vicinity of scale.

2. OBJECTIVE

The objective of this special committee was to test the accuracy of the Kilowate Track Scale as a coupled-in-motion weighing mechanism. The committee did not make judgments regarding the construction of the design of foundations and approaches to the scale. An investigation of the electronic system and instrumentation, the design, and the application were not a part of the committee's assignment. As requested by the Chief Engineer of the Georgetown Railroad Company, the test was restricted to 10 loaded cars for individual car weights, and 50 loaded cars for unit train weights. Georgetown Railroad Company did not permit the Committee to perform any other tests. No tests, therefore, were conducted using empty cars.

3. SUMMARY OF TEST PROCEDURES

The test procedure followed was to use the Webb static-lever scale as a reference scale to establish weights on cars to be used in the test of the Kilowate Track Scale. The reference scale was calibrated using the MPX-194, 80,000-pound test car. The calibration and reference weighing was conducted by F. J. Loyd. After minor adjustments to the electronic indicator, the maximum error on the reference scale was ±50 pounds. The reference scale was strain tested to 298,250 pounds using a loaded car, DCMX960, plus the test car. The total weight of the two cars was 100 pounds less than the sum of the individual weights.

Calibration started at 8:00 a.m. on February 26, 1985, and was complete, including strain test, by 8:30 a.m. Reference weighing of a 10-car loaded test train followed and was completed by 10:00 a.m. At this time, the committee split into two groups: F. J. Loyd, J. R. Kaberline, T. R. Loyd, L. W. Carroll and D. E. Keefer stayed at the reference scale to complete weighing of cars for the 50-unit train; C. T. Picton, G. L. Schenck, R. T. Taylor and W. G. Gemeiner went to the location of the Kilowate Track Scale to perform the in-motion test of the 10-car test train. The reference scale's accuracy was re-verified with the test car during, and at the completion of, the weighing of the test train.

Several runs were made with the 10-car test train from 11:00 a.m. to 3:30 p.m. to permit Kilowate technicians to calibrate the Kilowate Track Scale. At 3:30 p.m., the Kilowate technicians said they had completed calibration and were ready for the test. Since the reference weighing of the unit train had been completed, it was agreed to perform the unit train test at this time so that it would not be necessary to reweigh all 50 cars, if rain developed overnight.

The unit train test began at 4:45 p.m. and three tests (two passes of the 50 loaded car consist) were made pulling in each direction. This testing was completed at 7:30 p.m., which concluded the day's work. An error was made inputting the direction of weighing, by the Georgetown technicians, on the first run of the unit train pulling south. Therefore, this test run was voided.

The reference scale was tested to verify its accuracy on February 27, 1985, and the reference weighing of 10 cars for a test train began at 8:00 a.m. and was completed at 10:00 a.m. It was necessary to include five cars loaded with dry material in the test train because of the overnight rain. The reference scale accuracy was verified with the test car after completion of test train weighing.

The testing of the 10-car test train began at 10:30 a.m. One hundred weights were obtained in each of the four modes: pulling north; pulling south; pushing north; pushing south. The calibration established for the Kilowate Scale on the preceeding day was not changed, and it was noted that there appeared to be a shift in the weight of the cars in that they were generally weighing heavier. The amount of shift appeared to be different, depending on the direction of travel across the scale. This matter was discussed, however, the reason for the change was not apparent. The 10-car train consisted of gondolas, all the same length, loaded with limestone and weighing between 250,750 and 272,150 pounds. The 10-car train used to calibrate the scale on the previous day consisted of all open hoppers.

At 2:30 p.m., the testing of the Kilowate Track Scale by the committee was concluded.

4. SUMMARY OF TEST RESULTS[1]

1. Unit train test based on 50 car weights, 2-26-85 (50 loaded cars - 218,315 to 272,400 pounds).

A. Three tests[2] pulling downgrade to north at ± 2 mph:

	Test No. 1	Test No. 2	Test No. 3	Max Allowed[3] AAR & NBS H-44
Difference total train weight	.044%	.037%	.042%	.200%
Number cars exceeding 0.2%	29	21	29	N/A
Number cars exceeding 0.5%	8	9	9	N/A
Number cars exceeding 1.0%	0	1	0	N/A

B. Three tests[2] pulling upgrade to south at ±2 mph:

	Test No. 1	Test No.2	Test No.3	Max Allowed[3] AAR & NBS H-44
Difference total train weight	Void	.200%	.194%	.200%
Number cars exceeding 0.2%	Void	30	30	N/A
Number cars exceeding 0.5%	Void	14	15	N/A
Number cars exceeding 1.0%	Void	2	2	N/A

2. Ten-car test based on 100 weights each mode, 2-27-85 (10 loaded cars - 250,750 to 272,150 pounds).

	Pull North	Push South	Push North	Pull South	Max Allowed[3] AAR & NBS H-44
Max. difference ten-car weight	.219%	.420%	.237%	.340%	.200%
Min. difference ten-car weight	.132%	.324%	.001%	.002%	—
Number cars exceeding 0.2%	50	80	52	75	30
Number cars exceeding 0.5%	5	36	13	24	5
Number cars exceeding 1.0%	0	0	0	0	0

[1] Section 1.9.4 of the AAR Scale Handbook and Paragraph T.3.8.3.of the National Bureau of Standards' Handbook 44 specify the following basic maintenance and acceptance tolerances for determining individual car weights from coupled-in-motion railroad track scales:

(1) The sum of the static versus the sum of the motion gross weights of the test train in a coupled-in-motion test shall not differ by more than 2 lb per 1000 lb (0.2 percent).

(2) For individual car weights the basic maintenance and acceptance tolerances shall be applied to the errors on 100 car weights with:

a. No more than 30 car weights exceeding 0.2 percent error.
b. No more than 5 car weights exceeding 0.5 percent error.
c. None of the car weights exceeding 1.0 percent error.

The AAR Scale Handbook has no separate recommended practice for determining unit train weights. Paragraph T.3.8.4. of the National Bureau of Standards' Handbook 44 specifies the following tolerance for determining unit train weights from coupled-in-motion railroad track scales:

The difference between the motion gross weight values and the static gross weight values of the test train shall not exceed two pounds per 1000 pounds (0.2 percent).

[2] Tests refer to one pass of a 50 loaded car consist.

[3] Underlined values indicate non-compliance with AAR Scale Handbook Section 1.9.4. and National Bureau of Standards' Handbook 44, Paragraph T.3.8.3. Where N/A appears that means there is no

AAR "maximum allowed", because the AAR Scale Handbook does not contain a tolerance for weighing individual cars in a test conducted only to determine total train weight.

5. CONCLUSION

The Kilowate coupled-in-motion track scale may be useful for determining total train weights for trains containing loaded cars, detecting potentially overloaded cars, and other purposes. The tests conducted by the special committee of AREA 34 on the scale used in this report do not support the use of this weighing device for determining individual car weights in compliance with section 1.9.4. of the AAR Scale Handbook and the National Bureau of Standards' Handbook 44, Paragraph T.3.8.3. The results of this test are consistent with National Bureau of Standards specification for unit train weights, Paragraph T.3.8.4., but the AAR Scale Handbook does not endorse a separate specification for unit train weights. Note that no tests were conducted for trains containing empty cars, and that the stability of the scale's calibration could not be verified due to an unexplained shift in the weight of cars from one day to the next.

There have been at least two other tests on the Kilowate Track Scale since the Committee 34 test, and it is the AREA's understanding that there may be further tests.

MEMOIR

John William Hayes
1908-1985

John W. Hayes, retired architect, Burlington Northern Railroad, died on March 9, 1985 at St. Paul, Minnesota.

John was born November 30, 1908 at Portland, Oregon. He married Frances Lord in 1936.

Mr. Hayes began his railroad career in 1929 as an office boy and messenger for the SP&S Railway. In 1933 he was promoted to clerk and at that time attended Multnomah College in Portland, Oregon. He completed his studies and in 1936 became a registered architect in Oregon. John went on to become registered in Iowa, Wisconsin, Montana, Washington, Minnesota and Manitoba, Canada. In 1937 he started with the Great Northern Railway as assistant to the master carpenter at Whitefish, Montana. After serving in that position at many locations, John was transferred to St. Paul, Minnesota as assistant architect. He was promoted to architect in 1946 and held that position with the Great Northern and after the merger with the Burlington Northern until his retirement in 1973.

Mr. Hayes joined AREA in 1945 and in 1948 became a member of Committee 6, Buildings. He served as vice chairman of the Committee from 1961 to 1963 and as chairman from 1964 to 1966. John became a life member of AREA in 1974 and was elected Member Emeritus of Committee 6 in 1981. Mr. Hayes was also active in other professional organizations. He was a member of The American Institute of Architects, American Railway Bridge and Building Association, and served as president of The Interprofessional Club of St. Paul.

Surviving John are his wife Frances and three children Thomas, Mary and John.

Committee 6 and John's friends and associates express their sympathy and sorrow in his death.

R. E. Phillips

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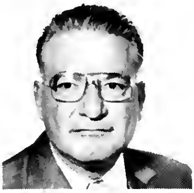

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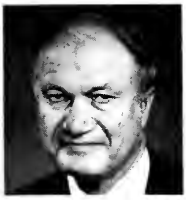

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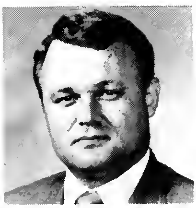

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MAY 1986

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Cover photo: Norfolk Southern unit coal train descends 2.2% grade between Ridgecrest and Old Fort on Asheville-Salisbury, North Carolina line.

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Figure 1 - Norfolk Southern freight on Murphy-Asheville line heads up the 4.3% grade of the Balsam Mountain grade Northeast of Sylva, North Carolina.

Four Ways and 4% + to Asheville

From a railway engineering standpoint, Asheville, North Carolina is one of the more difficult U.S. cities to get in and out of. Though east of the main range of the Smoky Mountains, Asheville is west of the eastern continental divide that marks the boundary between water flowing to the Atlantic and that flowing to the Gulf of Mexico via the Mississippi River. The area drains west via the French Broad River, whose deep gorge penetrates a range with the highest peaks (up to 6,684 ft.) in Eastern North America.

Four lines of the Norfolk Southern radiate from Asheville. One heads Northwest to Knoxville via the obvious but difficult route through the canyon of the French Broad River (see figure 7). Most of this scenic valley has a local road in additional to the railroad, but at a point beyond Marshall the railroad has the valley to itself in extremely mountainous conditions. Two other lines to Asheville, one approaching from the southeast from Spartanburg, South Carolina, and one approaching from the east from Salisbury, North Carolina, must crest the eastern continental divide.

The line from Salisbury does this by gaining almost 900 ft. in about 9 miles on a 2.2% grade with a total curvature of 2,776 degrees, the equivalent of almost 8 complete circles (see cover, figure 8 and map on page 162). One section uses 4 miles between points only about 3500 ft. apart. This extensive development includes four horseshoe curves and four tunnels leading up to the 1832-foot long Swannanoa Tunnel at the top of the grade at Ridgecrest. The valley in which the railroad gains elevation is like a hand with several finger-like side canyons. The track goes in and out of each side valley as well as making a very convoluted S-curve around a point called Andrews Geyser to gain elevation. The line is all single track.

The line from Spartanburg contains the steepest mainline grade in the United States, a 4.7% (250 ft. to the mile) single-track grade about 2.6 miles long (see figures 4 and 5). The top of the grade is at one edge a town called Saluda and the bottom is a point called Melrose along US route 176. The alignment of the grade follows along a narrow creek valley which has a dog-leg at roughly the half way point. Here the railroad crosses the creek and goes through a deep cut across the dog-leg. At the bottom of the grade is a runaway track where the switch is continuously lined for the runaway track except when a train approaches a timing circuit. The circuit then makes sure that the train is going slow enough between two

Figure 2 - Norfolk Southern freight heads for Canton, N.C. from Asheville over high deck truss bridge.

points before the switch is automatically thrown. Otherwise the switch remains lined for the runaway track which goes up a mountainside on a very steep grade. Although the switch was lined for this runaway track it showed no evidence of recent use and in fact a small tree was growing between the rails at one point. This indicated that the 4.7% grade is routinely operated in a safe manner (it should be noted that this is not the only main line in North America with a grade of 250 ft. to the mile, for this was also the maximum grade used in the design of the National Railways of Mexico line from Veracruz to Mexico City via Orizaba).

Figure 3 - Yard on Norfolk Southern at Canton, N.C. shows traffic generated by local paper factory.

Figure 4 - 4.7%! This photo looks upgrade at about the center of the 2.6 mile long 4.7% grade on the Asheville-Spartanburg line near Saluda, North Carolina.

The fourth line from Asheville is a branch to Murphy, North Carolina. Heading towards Asheville at the appropriately named village of Topton, the line starts to drop into Nantahala gorge, on a 4.2% grade known as Red Marble Mountain, until it comes along side the rushing waters of the Nantahala River and follows it nearly foot for foot beneath towering forested mountains. The line continues towards a recent alignment along the edge of a reservoir which it crosses on a large bridge. A few miles beyond Sylva is the base of Balsam Mountain grade which is 4.3% (see figure 1). The valley changes from about a mile wide

Figure 5 - Shown here is the obviously seldom used runaway track at the bottom of the 4.7% grade from Saluda.

Map at right shows the extreme circuity of Norfolk Southern Salisbury-Asheville line between mileposts 115 and 120 heading up to the eastern continental divide on a 2.2% grade.

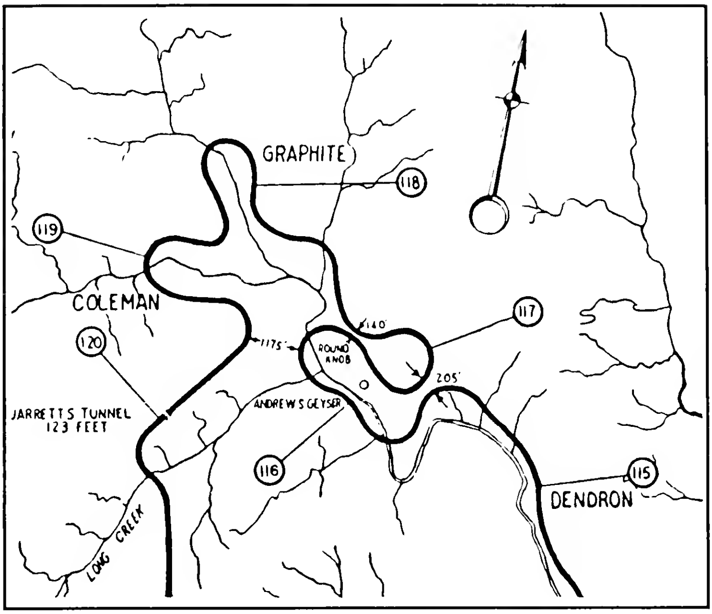

Figure 6 - Two levels and locations of track show in this photo. In the foreground is about milepost 116.8. Approximately 150 ft. below on the right is about milepost 115.5. The tracks get within about 200 ft. of each other measured horizontally near this point on the Salisbury-Asheville line.

Figure 7 - The Norfolk Southern line west from Asheville to Knoxville follows the French Broad River through the main range of the Smoky Mountains. This view is looking east towards the main range.

to perhaps 100 ft. wide within a very short distance as the railroad starts up from a small yard a few miles northeast of Sylva into the narrow valley up a side hill alignment, then cuts across a bend in the river on a bridge and deep cut. It continues twisting its way up to a wide spot in the valley where it crosses under a highway before going into another canyon shared with only a dirt road up to the town of Balsam.

Figure 8 - Norfolk Southern Unit Coal Train at bottom of 2.2% grade on the Asheville-Salisbury line during rainstorm.

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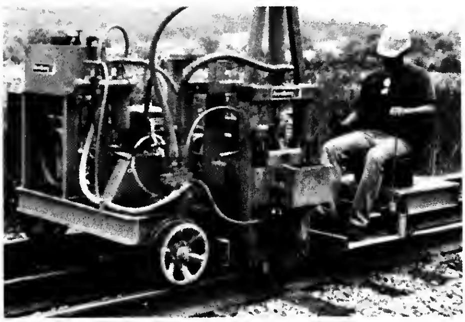

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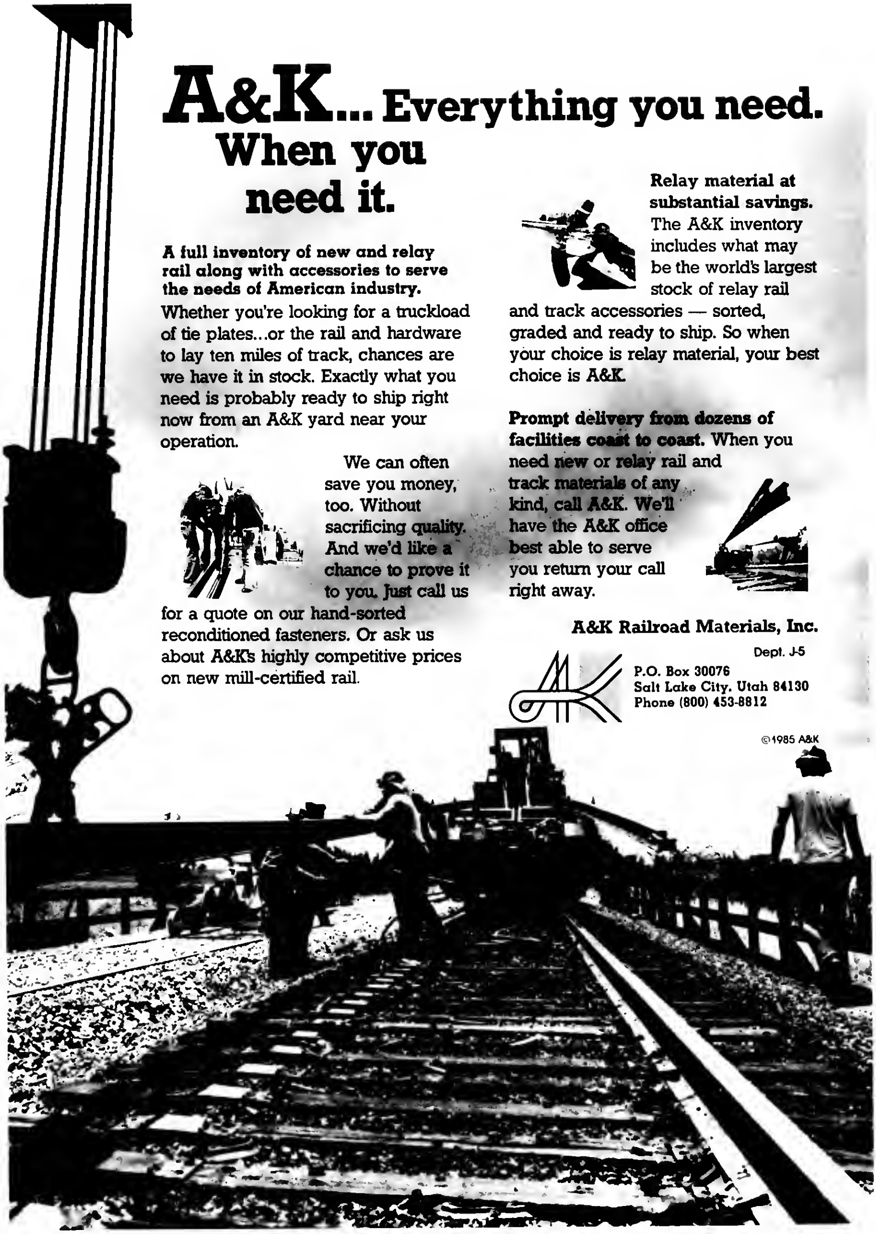
Rail Changed Out After 103 Years in Original Location

While the core of railway engineering work in North America today is the maintenance of high density, heavy duty main lines, it is also true that an important skill is the ability to economically handle the maintenance of lighter duty, lower speed lines that are vital to the economies of the areas they serve. An example of such a line is the 242 mile long Columbus and Greenville Railway in Mississippi, which provides the only rail access to a large portion of the flat, agriculturally rich "Delta" area around Greenville, Mississippi, including such cities as Cleveland, Hollandale, and Indianola. Commodities handled include rice, cotton, feed for commercial catfish growers, and many other items. While portions of the Columbus and Greenville are 112 lb. welded rail, its management has prudently and safely attempted to get the maximum life from lighter weight track material. An example of their success in this regard is shown in the above photo taken on February 24, 1986 near Elizabeth, Mississippi. Here a small rail gang is replacing 103-year-old 60 lb. rail with 64-year-old 90 lb. rail. While maximum car weight allowed on this line will not be changed from 263,000 lb., the heavier rail should provide many more decades (another century?) of service on this line, with perhaps an increase in speed. The 103-year-old rail was believed to be in the position in which it was originally placed in 1883.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Prefabricated Turnouts For Canadian National

J. T. McBain*

Presentation to 1986
AREA Technical Conference
Chicago, Illinois, March 24, 1986

Good Morning! I would like to thank you for the opportunity of speaking before this Technical Conference and to present CN's efforts in the field of prefabricating turnouts.

The following areas will be discussed :

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2. Pre-plated Turnout Packs - 1984
3. Panelized Turnouts - 1985
4. Productivity Improvements
5. Future Plans
6. Comparative Summary

1. Background

Why is CN prefabricating turnouts ? To obtain an answer, we must go back in time to the introduction of the 100-ton capacity car.

The higher axle loading resulting from the 100-ton car coupled with increased volumes of rail traffic (including the more frequent usage of unit trains) resulted in significantly increased wear and dynamic loading on the plant.

Turnouts in particular required heavy maintenance with the increased traffic. The turnout area with its conventional joints and fastenings was the weakest yet most expensive link in the track structure. A stronger turnout requiring less maintenance was needed.

CN 's response to this problem was the design and manufacture of a new heavy duty turnout that could stand up to today's tough tonnage. This " Super Turnout " is a 136 lb., lag screw, Pandrol clip and hardwood tie turnout. There are several major differences between it and a conventional turnout:

A) General :

Conventional Turnout	136 lb. Super Turnout
- Made up of standard rail	- Made up of Premium rail with transition rails before and after turnout
- Fastened with cut spikes	- Fastened with lag screws and Pandrol clips
- Softwood and hardwood ties (for mainline)	- Hardwood and concrete ties

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B) Individual Components :

Standard	New Design
i) Standard Double Shoulder Plate	**Switch Plate**
- Dimension: 7" x 14" - Fastened to tie by 2 cut spikes	- Dimension: 7" x 18" - Fastened to tie by 4 lag screws and 2 Pandrol clips
ii) Hook Plates	**Double Switch Plates**
- Fastened to tie by by 6 cut spikes - Rail held by 2 hooks and 2 spikes	- Fastened to tie by 4 or 6 lag screws - Rail anchored by Pandrol or hold down clips
iii) Standard Guard Rail	**New Design Guard Rail**
- Same height as running rail - Short guard rail results in more frog batter - Minimal bracing at centre and at ends	- Raised , assures proper truck alignment through frog area - Longer guard rail results in less frog batter - Braced at approximately 2' intervals
iv) Standard Frog	**New Design Frog**
- Held in line by hook plates - Fastened to individual ties only - No gauge plate	- Set on integral base plate which spans 5 ties - Anchored by Pandrol clip to base plate - Gauge plates at toe and heel of frog maintain proper gauge

But the new 136 lb. lag screw turnouts come in various sizes, are complex and require precise placement of plates. In fact, there are over 980 lag screws and 2100 components in a no. 12 Super Turnout. With the advent of 136 lb. turnouts came increasing usage of no. 16 and no. 20 turnouts, the likes of which our field forces had never seen before. Due to the precision made nature of these high-speed turnouts, achieving quality assurance in rough and mountainous field conditions had become a significant problem.

In addition, CN's Five Year Plan issued in 1983 called for installation of roughly 100 of these Super Turnouts every year on our Mountain Region alone.

So CN Engineering was charged with the task of installing large numbers of quality turnouts utilizing the shortest possible work blocks. The solution was found through the prefabrication of turnouts.

2. Pre-plated Turnout Packs - 1984

The first mass production attempt at prefabricating turnouts occurred in early 1984.

A bright, modern facility was leased in Edmonton, Alberta for the purpose of prefabricating 136 lb. Super Turnouts. The facility, located adjacent to a secondary mainline, consists of 3 basic areas:

- Material receiving and storage area
- Shop area for turnout prefabrication
- Shipping area

The turnout prefabrication process began by shipping the necessary hardwood ties and turnout material to the Turnout Assembly Plant. In the receiving area,it was unloaded by a 7 ton overhead crane. The turnout material at that time was delivered from our Roadway Stores in "pack form". That is, each turnout was made up of a "switch pack", a "guard rail pack", and a "frog pack". If any parts were missing you had to scavenge them from other turnout packs.

The next step involved bringing the turnout components indoors on electrically winched carts. The material was then distributed by 5-ton overhead cranes onto special assembly jigs. These jigs were built to improve productivity by eliminating measurements and to ensure that proper spacing and alignment were maintained.

The turnouts were then assembled using electric and pneumatic powered tools.

Incidentally, an indoor facility is required for prefabrication as the outdoor temperature hovers around - 30 degrees C (or -22 degrees F) during the winter prefabrication season.

Once the turnout was fully assembled and met CN Track Standards, the rails were removed and retained for shop re-use, the fastenings and other loose material were packaged in a shipping box, and the ties, with plates attached, were numbered and strapped into bundles.

The Pre-Plated turnout consisting of tie bundles, material box, frog and switch points was then loaded by overhead crane into waiting gondola cars and shipped complete with reassembly drawings and instructions to the installation site.

At some later date, a 25-man turnout gang would break open the bundles and lay out the numbered ties in proper sequential order and spacing on an adjacent track or flat area. The loose components and fastenings were then distributed onto the ties. The last step involved in reassembling the turnout was laying the 136 lb. premium rail (which had been shipped to the job site separate from the Pre-Plated turnout) onto the ties and securing the fastenings and loose components. Once the fully assembled turnout was checked, it was ready to be skid into the mainline.

The actual operation of installing a prefabricated turnout (be they Pre-Plated or Panelized) will be discussed in more detail later in the presentation.

The 1984 experience with Pre-Plated turnouts taught CN several valuable points:

A) Large complex turnouts could be installed quickly and accurately using prefabrication techniques.

B) The prefabrication of turnouts could be made cost effective if the requirement of having to reassemble the Pre-Plated turnout in the field could be eliminated.

The answer was found the next year with the development of Panelized Turnouts.

3. Panelized Turnouts - 1985

What hindered CN from utilizing Panelized turnouts at the start was the difficulty of shipping them to the field. A method had to be found whereby wide and long switch tie panels could be economically transported without abnormal dimensional load shipment restrictions.

CN's Engineering and Equipment functions met this challenge with the design of the " Panelized Turnout Transporter Car " or " A-FRAME CAR " for short. See Figure No. 1

Factors involved in the design of this car were :

A) Turnout panel transporter car designs in use on other railways.

B) Dimensional load shipment restrictions - the car had to be easily shipped anywhere on our mainline at any time.

C) Severe climactic conditions encountered during unloading of car in winter months.

D) Low maintenance requirements - ie., a simple design

E) Availability of cranes to unload panels from car.

The final design is a simple, easy to use car which takes advantage of CN's existing crane fleet.

The cars were converted from scrap and " bad-ordered " depressed deck auto transporters (which were surplus to our automotive requirements) at CN's Pointe St. Charles shops in Montreal,Quebec. Twenty-one cars were built for a total cost of $840,000.

Each car is 89 feet long and carries 180 feet of turnout panel. In other words, a complete no. 10 or no. 12 turnout (including frog, rail and head block ties) can be carried on one A-Frame car. An accompanying flat car is required for shipping a no. 16 or no. 20 turnout.

The Panelized Turnout is assembled at the Turnout Assembly Plant the same way as before but now the turnout is only cut into easy-to-reassemble panels :

Turnout Size	No. of Panels	Plant Manhours Required
10	4	140
12	4	175
16	5	320
20	6	360
20 Equil.	6	390

The maximum weight of any panel is 12.0 tons. Most are between 6 and 10 tons.

When loaded, the highest point on the car is 19 feet from the top of rail. Since the maximum height is lower than an enclosed tri-level auto transporter car, it can be shipped anywhere on our Mountain Region mainline at normal freight speeds.

When the A - Frame car arrived at the installation site, a 40-ton locomotive crane would unload the panels onto a nearby backtrack or level site.

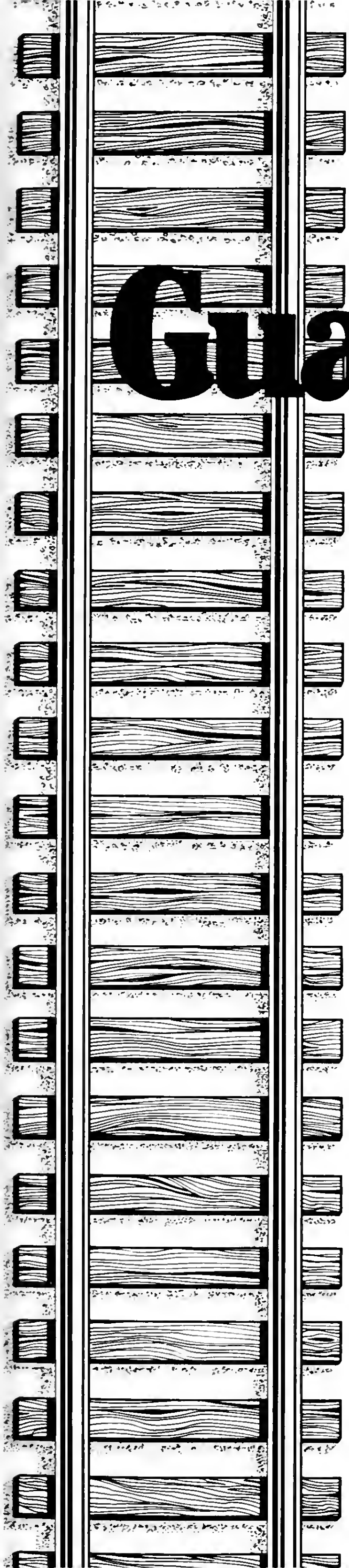
At some later date, a 25-man turnout gang would install the panelized turnout. They began by cutting and removing the existing turnout in panels. These "Part-Worn" panels were stockpiled adjacent to the track for future re-use. The next step involved grading and trimming the ballast section. Where necessary, geotextile was also installed. This ballast work was usually done by both a rubber tired front-end-loader and a skidder. The new turnout panels were then placed on top of the mainline. The skidder, using its winch to pick up the front end of the turnout, then pulled it in on top of skidder rails. With the help of a locomotive crane picking up the heavy end of the turnout, the skidder rails were then removed from underneath the turnout. The turnout was then temporarily bolted together and the signal apparatus was installed. After the turnout was ballasted and surfaced, it was ready for traffic. The panel joints were later welded by a crew working generally in the same work block as the installation gang, which may have been working on the next turnout down the line. A no. 12 turnout, the most popular one installed that year, only required a six hour track block for complete replacement.

In addition to improving the method by which CN installed prefabricated turnouts, productivity improvements were also made at the Turnout Assembly Plant.

4. Productivity Improvements

Industrial Engineering techniques were applied to the plant to improve material handling methods and to reduce overhead costs :

A) Turnout material was shipped to the Turnout Assembly Plant in bulk shipments instead of unique turnout packs. This was made possible by setting up storage racks inside the plant which organized all the many turnout components into an easy to find format. This method permitted our Roadway Stores to ship material straight from the supplier to our facility in Edmonton, thereby eliminating the need of temp-



orarily packaging and storing the material. Annual savings of $75,000 were realized by improving the material handling method.

B) A forklift was obtained for the plant to help speed up the material selection process.

C) Rails were received from our butt-weld plant in Winnipeg, Manitoba in custom cut lengths. This allowed for optimum turnout panel design as rail length was no longer a constraining factor.

D) Glued insulated joints were thermite welded into the closure rails at the plant instead of the installation site. A production style thermite weld jig was set up at the plant to lower the time per weld.

Goals of reducing plant overhead costs and of maximizing the benefits of handling and installing Panelized Turnouts are an ongoing effort and will continue in the future.

5. Future Plans

As most of you are aware, North America's first concrete tie turnout, a no. 20, was installed by CN in 1984 in British Columbia.

In 1986, two additional no. 20 concrete tie turnouts will be installed on a high tonnage, coal haul portion of our Yale subdivision in Western Canada.

If you will recall, when installing new Panelized Turnouts, the old turnout was removed from mainline service intact in panels. While this turnout may no longer be suitable for mainline usage, it would often have considerable useful life on a lighter density line. The "Part-Worn" turnouts which require rehabilitation before reassignment to another line, will be sent to the Turnout Assembly Plant in Edmonton.

Before CN had a method of transporting turnout panels, the old turnout was completely dismantled and returned to our Stores for scrap value compensation. Now we are in a position to obtain a "second-life" out of the turnout for a relatively minor effort.

6. Comparative Summary

A comparison of the three methods of installing 136 lb. lag screw and Pandrol clip turnouts utilized by CN is presented in Table No. 1. The "Conventional Method" referred to is the old standard way of installing turnouts whereby the ties are installed in one pass, and the rail and switch material installed in the next pass.

As indicated by the figures in Table No. 1, Panelized Turnouts require :

A) Less block time.

B) Less manhours to install.

C) Less total cost to install,particularly in the field. Cost of accommodation of the installation gang was not included in this comparison. If it were, Panelized Turnouts would become yet more economical as that method requires less field time than the others.

D) Permit reassignment of the old "Part-Worn" turnout released from mainline service to a lighter density line.

That is the end of my presentation today. The new designs and methods of installing heavy duty turnouts have been challenging, but the benefits have been rewarding and interesting.

If any of the material I have presented today can be of help to your railway, just let us know and we will do our best to share the knowledge. Thank-You and Good-day.

Table No. 1 Turnout Installation Method Comparison *

Description	Conventional	Pre-Plated	Panelized
Work Block Required (Hours)	8	8	6
Manhours Required to Install			
Plant :	0	175	175
Field :	900	790	565
Total :	900	965	740
Total Cost Excluding Material			
Plant :	0	$4200	$4200
Field :	$15100	$13500	$9800
Total :	$15100	$17700	$14000

* For a no. 12 136 lb. turnout, undercutting not included

Figure No. 1 Turnout Panel Transporter Car

Influence of Performance Requirements on Design and Construction of Switches and Crossings A Contractor's Viewpoint

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ABSTRACT

After briefly referring to the circumstances in which a leading UK supplier of Trackwork finds itself engaged in a world wide marketing campaign, the paper discusses the way in which certain performance factors, seen as independent variables (axle weight, speed, annual gross tonnage hauled, business characteristics, and layout complexity), affect the nature of the product seen as dependent variables (Rail section, switch design, alternative manufacturing processes for crossings). In dealing with switches reference is made to the selection of switch rail section, switch entry angle, and switch design. In dealing with crossings the problems associated with eliminating impact forces caused by gaps in the rail and by unsatisfactory wheel profiles, leading to the various alternative manufacturing solutions, are explored.

Trends in the design and manufacture of Trackwork for Heavy Haul, Mixed Traffic and both Mass and Light Rapid Transit systems are reviewed drawing on the world wide marketing experience of Henry Boot Railway Engineering Ltd. Some indication is given of the problems brought about by the decline of the Railway market in UK.

The question whether existing AREA standards for either or both Switch and Crossing design require modification in the light of current technical development is discussed and in conclusion some observations are offered on alternatives which are available, for Heavy Haul and Rapid Transit Trackwork in US.

1. Introduction

The presence in the export market of a British supplier of Trackwork, or, as it is referred to in UK, Switch and Crossing Work (S & C) is no new thing. For more or less as long as there have been railways, British entrepreneurs have been actively engaged in the railway business all over the world. In that time there have been many changes in economic and political relationships between Britain and the rest of the world. There have also been changes in technology, and in the internal economy of the UK. Nevertheless it is still true that exports are of great importance to the British railway supply industry. However the outlook for exporters has changed emphasis over recent years, both as regards the types

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of material called for and as regards the nature of the package on offer. The realisation of this has led Henry Boot Railway Engineering Ltd (HBRE) to a thorough survey of the world market for S & C material. Some of the results of this market research form the subject of this paper, and suggest that although "Heavy Haul" and "Light Rapid Transit" (LRT) are not notable features of the railway scene in UK, the British S & C industry has nonetheless plenty to offer in the field of design and manufacture for these types of traffic. It also has much to offer in conditions where speed and frequency of trains rather than sheer axle load are the criteria.

2. Performance Requirements

One must expect to encounter some diversity of S & C design from country to country. Obviously, much of this diversity will be a consequence of an evolutionary process in which component design has developed in response to the experience of maintenance engineers seeking economical solutions to problems caused by the traffic of the particular railways concerned. At the same time it has to be recognised that there are other, non-technical factors which sometimes affect decisions about technical policies. Where these factors operate they will nowadays generally tend towards producing uniformity rather than diversity. However the technical factors generally regarded as leading to diversity in design include axle weight, speed, annual gross tonnage hauled, layout complexity. A few remarks on these aspects derived from our market research follow, with particular reference to the permanent way design features which they are generally regarded as affecting, viz:-

Switch Design:
- Entry Angle
- Planing Length
- Switch Length
- Choice of Section

Crossing (Frog) Design:
- Angle
- Choice of fixed or movable point or wings coupled with method of manufacture

2.1 Axle Weight and Gross Tonnage Hauled

2.1.1 Influence of Axle Weight and Tonnage on Rail for S & C.

From the point of view of plain line design, speed, axle weight and annual gross tonnage combine together to control the dimensions of the rail, through the mechanisms of fatigue, wear, and rail head crushing (ref 3). The same factors affect the design of tie adopted by a railway. (It might be thought that they would also influence tie spacing, but whilst railways using heavier axle weights do tend to use closer tie spacings, there are distinct limits at both ends of the spectrum to the practicable range of this

parameter, which may for this reason be seen as something between an independent variable and a constant. Plain line tie design of itself is not considered in this paper.)

With the possible exceptions of the switch blades and parts of the crossing assembly, the rail used by any railway in the manufacture of S & C work will be the same section as is used on its plain line. However, it does seem worth while to observe that the presence of a multiplicity of different sections amongst the world's railways operates rather to facilitate protectionism than open competition. In this connection the tendency of administrations in the Eastern Hemisphere to specify a UIC rail section can only be seen in the long term as an advantage. Fortunately HBRE have access to supplies of most American sections in common use since these are now rolled by the British Steel Corporation (BSC) in steels which are acceptable to US railway authorities.

It will be well known that on the other hand the steel from which the rail is made may well be different in S & C work from the adjacent plain line. A considerable variety of alternative materials are available, including the moderately hard steels covered by the "A" and "B" grades of the UIC 60 - O specification, the highly work hardenable but difficult Austenitic Manganese (only available as rolled material from BSC and less to be recommended than the more modern solutions to the problem of obtaining a highly wear resistant rail), the naturally hard Chromiumn alloy pearlitic steels, the various heat treated and/or head hardened rails, and lastly the newcomers in the field, the Enhanced 1% Chromium rail produced by BSC at Workington, with its surface hardness of 370 to 390 BHN.

2.1.2 Influence of Axle Weight and Tonnage on Switch Design.

The range of maximum axle weights on standard gauge railways is presently from roundly 13te as a minimum for "Rapid Transit" style undertakings to as much as 60te in special situations such a steelworks. The heaviest axleweights on trunk haul routes are of the order of 40te. Annual gross tonnages vary from the purely nominal up to about 40M per annum.

At the lower end of this scale a switch blade made from the standard plain line rail of the undertaking is perfectly suitable from a structural point of view. Unless other factors (eg speed, q.v. below) supervene, it becomes a matter of economics whether it is proper to accept such a design or whether it is preferable to go for an alternative such as a thick webbed or a reinforced switch. British Rail (BR) for example achieves quite acceptable lives from its standard BS11 "Normal" rail steel switches under both high speed and heavy (25te) axle load traffic provided that the turnout is of a fairly flat angle. On the other hand the shorter turnouts necessary in terminal areas call for wear resisting rail for the manufacture of switches even though speeds may be relatively low and the only heavy axles using such a layout may be those of locomotives (ie 20 -21te each).

When a rail which is stronger than the standard plain line variety is required, the designer has the options of specifying:

(a) Rail similar in section to standard plain rail but either naturally hard or head-hardened.

(b) Standard, naturally hard, or head- hardened rail as above but with the addition of reinforcing bars.

(c) Rail of shallower depth than the plain line rail but with a thicker web. Such rail can be either symmetrical about its vertical axis in the "as rolled" state, or the foot can be mainly on one side of the web. Such rail is available with the same choice of metallurgical properties as mentioned above.

(d) As (c) but the rail has the same depth as the plain line rail.

Many undertakings still use option (a) and where they do so, there tends to be a cost involved in moving to option (b),(c), or (d) which encourages inertia. Such railways tend to operate at either low tonnage or low speed. Where high performance is required however railways now increasingly specify one or other of options (b), (c), or (d).

Option (b) - the use of reinforcing bars - is standard AREA practice. Option (c) - the use of a shallow depth, thick webbed switch rail - is a practice widely adopted on the European continent and on many less highly developed undertakings in Asia (see below) though not by BR to any extent. Where this last option is adopted, the switch rail used is, in the "as rolled" state, squatter and typically about 10% heavier than the plain line rail with which it is associated. This increased weight is provided to make it easier to forge the transition between the thick web and normal rail cross-section at the heel of the switch.

Option (d) will be discussed further under section 4.2.1.below.

A switch rail of special section has a number of advantages over one made from standard rail. These advantages are:

(1) The foot of the stock rail on the switch rail side does not require to be machined. This reduces time on the planing machine and hence cost of manufacture (See Table 1).

(2) The change in the shape of the switch rail near the switch tip markedly increases the strength and stiffness of that part of the switch blade compared with either a standard or reinforced design.

(3) Compared with a reinforced switch, the use of metal in the web is made more efficient by

replacing the composite with a homogeneous section. When a thick web is used, one avoids the need to drill numbers of holes through the web of the switch rail and subsequently to fill those holes with bolts. In our view the bolt holes present, in these days of high quality rail steel, a worse hazard than the one they are intended to obviate, whilst the bolts increase the maintenance task out of proportion to the possible advantage gained.

(4) Opportunities are offered for simplifying the system for fastening down the stock rail.

The assembly involves:-

(1) Since the Switch Rail foot is 25mm or so above the Stock rail foot, there is a two-level slide baseplate. Typically the upper level which carries the moving switch tongue, projects over the foot of the stock rail, holding it in place against roll-over forces. Alternatively an elongated clip can be passed under the switch rail to secure the inner edge of the stock rail foot.

(2) With the stock rail thus secured against roll-over, it can be fastened down on the field side by a simple plain line clip, e g., Pandrol.

2.1.3 The Influence of Axle Weight and Tonnage on Frog Design.

The problem with Frogs is not so much that heavy axle loads cause any particular problem as regards the overall structural strength of the assembly, but rather that because of disturbance to the lateral and vertical trajectory of the wheelset caused by the discontinuities inherent in the design, the contact stresses are much greater than in plain line. Therefore with heavier axles normal grade rail steel is unlikely to be hard enough to resist abrasive wear nor strong enough to resist crushing. Hence the use of some form of high duty rail in crossings, (whether frogs or obtuse crossings). This takes the form of :

a) A built-up assembly in a hard rail

b) A built- up assembly using a cast vee-point, as in the AREA rail-bound frog.

c) A built-up assembly using a welded Vee-point.

d) A Monobloc Casting

e) A Movable crossing (either a frog with movable nose or movable wings or a switch diamond).

The use of one or other of these features is now commonplace, and the point will be stressed later in the paper, that the rail bound frog is no longer necessarily the right answer in all cases for "Heavy Haul" situations.

2.2. Speed

From the point of view of S & C design, the significant aspect about speed is not the route speed of the railway concerned, but the speed at which it is required that trains should pass over the diverging track of any turnout. In European practice at the present time there is a strong tendency towards increasing turnout speeds. This is due to the realisation that in the geographically larger (and incidentally economically dominant) countries the railways must, if they are to stay in the passenger business, equal or better city centre to city centre timings achievable by air or automobile over moderate distances (say 300 1000km). This predicates a frequent service with high average speeds such as that operated by BR's Intercity Sector. Where as in UK junctions and intermediate stations having complex layouts are closely spaced high average speeds cannot be obtained without being able to traverse turnouts at speeds approaching line speed.

This means long switches with small switch entry angles and flat crossings. In the case of obtuse crossings (diamonds), the crossing angle does not have to be very flat before the length of the gap which the wheel must cross becomes unacceptably large and resort must be had to switch diamonds, which have thus been commonplace for many years, but if very flat common crossings (frogs) are required, there comes a point on these also where continuous support becomes desirable if not essential. It is to meet situations such as these that the swing nose frog has been developed.

Even where speeds over the diverging arm are not so great, as on LRT undertakings or as is the case on many railways in Asia and Australasia there is for passenger comfort and for the minimisation of wear both of track components and rolling stock, a need to review the present design standards for switch entry angle. Traditional approaches to switch design tended to use empirically derived models based on observations taken in available rolling stock of a necessarily limited range of dimensions. When radical changes to the parameters are made (eg change of gauge or change of bogie wheelbase) the empirical formulae do not necessarily give the right answers. Much basic research has been done into these problems recently (eg ref 4,5) and a firm such as HBRE with access to the results of such research has the capability to investigate design requirement from first principles. A rationally based design package can be produced, even where the business requirement may be far removed from the conventional norm.

3.2.2 Heavy Haul experience in Australia

Here, as in many other countries, local industry developed and S & C importing was phased out long ago. However, more recently the historic railways, which are rapidly working their way out of the difficulties produced by the

multiplicity of gauge changes, have proved receptive to new design ideas. Much rationalisation of track gauge means that long lengths of unbroken 1435mm gauge track now exists on interstate routes of the Australian National, New South Wales, Victorian, and Western Australian networks. This has made possible substantial freight traffic flows with axle loads up to 25 tonnes at speeds of 100kph and also important passenger flows, notably suburban and "Rapid Transit" in style. Generally passenger train speeds are not above 100 - 130 kph, although the NSW railway has attained the local record speed of 180kph with its UK designed High Speed Train.

In modernising their networks for these conditions the Australian railway administrations are looking more and more at European designs. Typically this means turnouts with angles of 1:24 to 1:28 for main line situations requiring trains to diverge at moderate speed. The use of movable frogs is being considered, but where fixed frogs are specified these are almost invariably either cast AMS monobloc or Welded Vee frogs made from high strength rail. Switches will be in thick-web, possibly asymmetric, rail following European practice and the preferred fastening will be Pandrol.

The development of the heavy haul lines to Mount Newman, Tom Price, Hamersley etc, has presented further opportunities. The designs of S & C used by the previous generation of railways were inadequate for the loads to be carried on the new lines. Naturally those responsible for track design looked to other heavy haul railways such as in USA for initial ideas. As a result the first designs followed AREA practice very closely, with reinforced switches, loose heels, and rail bound frogs. However it was soon found that for the extremely heavy axle loads and gross annual tonnages of these railways S & C to these designs had a short life and required a lot of maintenance. For these reasons engineers on those railways have begun to look elsewhere for help in solving some of the problems created by their own success. As a result of this policy turnout design has been revolutionised.

Both the Mount Newman Railway and Hamersley now use swing nose frogs. Whilst they still use reinforced switch blades they have replaced the loose heel design by flexible switches and both have improved their switch geometry. Both use Pandrol clips. Hamersley have gone over to prestressed concrete bearers.

HBRE have cooperated with Mount Newman in the development of swing nose frogs to our own design. So far 33 of these frogs have been installed between Port Headland and Mount Newman, on a route carrying axle loads up to 40 tonnes at 75kph. Each train consists of 180 cars and three locomotives and grosses almost 24000 tonnes. The annual gross tonnage is 40 million. The rail used is 136lb RE in 1% enhanced Chrome steel. The turnouts with an angle of 1:15, incorporating Pandrol fastenings, self-lubricating slide baseplates and jarrah cross-ties are installed inter alia at the ends of the twelve major passing loops.

Thus they see all the traffic of the main line. The first movable frogs were installed in October 1982 and their performance has been so good that their assessed life has been extended from the seven years assumed in the initial assessment to ten years which is the expected life of the plain line running rail. This compares with a life of three years which was all experience indicated was obtainable from the original rail bound manganese frogs. Even on the basis of seven years' life the design was reckoned by Mount Newman to result in an annual saving of $A 3000 and the reassessment to ten years life improves this to $A 4321 per crossing per annum.

Some details of this design and details of the economic assessment are given in the attached figures and table IV.

It is worth noting that both the redesigned flexible switch and the movable frog are worked by standard AREA drive mechanisms. There are no guard rails at the frog, and satisfactory run-on and run-off is achieved at the frog with worn (i.e. false flanged) wheel treads. To date no weld repairs are known to have been carried out, although some slight head checking has occurred. HBRE engineers consider in the light of experience with these crossings that the only immediate improvement that could be made would be some minor redesign of the rail head to reduce this checking.

4 North America

4.1 General

The North American market presents great contrasts from most of those described above. It might seem superfluous to go into any detail in describing it for the purposes of this paper, but there are some features which deserve emphasis.

Firstly there is the great size of the undertakings individually and of the network as a whole. Amtrak alone operates over more mileage than the whole of BR. Any of the major corporations easily outclasses any of the lesser railways mentioned in section 3.2 above, whilst the network as a whole is something like twenty times the size of BR.

Secondly one must mention the obstacles which present themselves to the prospective importer into the States, namely the highly developed existing industry and the very sophisticated standards and specifications with which quite rightly importers are expected to comply. It indeed says something for the open nature of competition in USA that UK exporters heve managed to secure contracts at all in USA, where everything which enters from Britain has to cross an ocean.

Thirdly come contrasts in traffic and operational practices. Axle loadings at 30 - 35 tonnes are higher than on any main line railway in Europe....Indeed than anywhere else covered by this survey except for the heavy haul railways in Australia. Speeds on the other hand tend to be low, although it is well known that there are routes with very high overall speeds. Wheel tyre maintenance is not so frequent as

is usually the case on major European railways (but of course the latter are not famous for turning in large annual profits). Train length and weight, and gross annual tonnages on many routes are orders of magnitude greater than in Europe, if not in Australia.

Fourthly one must mention the weather. It is known that the winter climate of much of the US is very much more severe than that of Western Europe, and one must beware of drawing too close a parallel between US and Australian problems and practices since by US standards Australia does not have a winter at all.

At the same time the outside observer sees the same trends developing in US railways as are noticed elsewhere, namely that it is possible to distinguish between mixed traffic, heavy haul, and LRT operations. This growing trend calls into question whether the time might not be ripe for AREA to add to its range of standards, designs which are appropriate to the new operations. A further question to which the last part of this paper will address itself is whether the new techniques of switch and frog manufacture ought also to find a place in these standards.

4.2 Switches

The outsider looking at AREA practices bearing US conditions in mind feels no surprise that rail weights are generally higher here than elsewhere, and he can understand the reasons for such details as "Switch Raise", even though he may wonder whether they are really absolutely necessary. Some other aspects of practice however cause more surprise, and these will next be explored a little more closely.

4.2.1 Reinforced or Thick Webbed Switches?

Considerable mention has been made in Section 2.1 above, of the use of thick web rail to make switches, and the advantages of using them were there discussed. In section 3 above we have shown how thick webbed switches are gaining in favour with many railway undertakings. These observations and experiences give us confidence to assert that the thick webbed switch has sufficient advantage over all its competitors to warrant offering this type of switch as an alternative when invited to tender. For this reason HBRE have developed a form of thick webbed switch in which the switch and its associated fittings are completely interchangeable with the relevant pre-existing design of reinforced switch. In order to achieve this the switch rail instead of being shallower than the standard rail is the same depth.

This design is option (d) as referred to in 2.1.2 above. HBRE are currently engaged in market research and economic investigation to see what future such a concept might have. Certainly at first sight it appears that the project could have attractions. The design is simpler and easier to make than the conventional AREA switch with reinforcing bars and should be cheaper because of the shorter workshop time involved. It would be quite possible to make the switch with

AMS inserts using existing techniques. Being a straight like for like replacement the on site costs would be the same as for the conventional switch, and finally we would expect the life to be the same or better.

4.2.2 Switch Entry Angle

At first sight one might expect that the supply contractor would not wish to comment on such design parameters as the switch entry angle, the planing length, on such basic choices as whether or not to incorporate a "point rail rise" in the design, or on the choice of loose heel or flexible switch. However since the contractor is obliged to look with some care at the drawings of the article he is making, it is difficult to avoid making comparisons. When these comparisons are made it appears that on some of the above aspects, AREA practice is a bit conservative. To take the question of switch entry angle and planing length, it is found that for similar frog angles, AREA turnouts have shorter planing lengths and larger switch switch entry angles than for example BR turnouts. These differences are shewn in detail in Table V.

These differences are evidently linked with other differences in practice between US and BR practice, such as the 39ft standard rail length, and the use of the "loose heel" instead of the "flexible switch" with a fixed, or even a welded heel joint. These differences in practice lead to quite far-reaching differences in switch design, as Table VI shows. Whatever method of assessing the permitted speed over the switch it is evident that the for a given frog angle or for a given lead length the AREA design will either involve a slower speed or the acceptance of a greater damage rate to the switch and to rolling stock passing over it, than the BR design. This seems a rather high price to pay for sticking with the "loose heel" principle. Although BR designs are quoted here other European style turnouts exhibit similar features when compared with AREA designs and as longer rail lengths become available to US railways so facilitating the manufacture of longer switches, we would strongly recommend that AREA should at any rate have on offer a range of turnouts following European design practice. It is recognised that if an existing layout is cramped longitudinally either by restraints imposed by the shape of a site or by switch drive installations the longer overall length of turnout needed for any given frog number may prevent the use of the modern design. However from BR's experience it is usually possible to overcome such problems, particularly if the remodelling is accompanied by a measure of rationalisation of layout.

4.2.3 Switch Raise

A feature of AREA switch design which is strange to European eyes is the "Switch Raise", which is understood to be provided so that even if the wheel tyre is hollow worn, the back of the tread will not bear on the stock rail running table during its transfer onto the switch rail. It is claimed that wheels become very badly hollow worn on US

railways, making this technique of great value. On the question how badly hollow worn US tyres become, it may be doubted whether they become significantly worse than anywhere else. Whilst the authors have not been in a position to make large numbers of measurements (for obvious reasons!), information available suggests typical figures of 6mm in US compared with 4mm on BR. Either value is more than sufficient to ensure that the tread will bear on the stock rail as it crosses it. There is also plenty of evidence to be seen on BR to show that the tread back does indeed bear on the stock rail as well as on wing rails and on splice rails when traversing frogs. There is no evidence on BR to suggest either that the resultant crushing of the stock rail head materially reduces its life or that the associated lifting of the wheel induces any serious additional risk of derailment due to the wheel climbing over the switch rail. It has to be remembered in this connection that the lateral force on the wheel flange at the point of contact with the switch is the result of two effects. The first results from the fact that two point contact inevitably occurs during the passage of a wheel from stock rail to switch rail. The resultant perturbation of the rolling radius differences produces a modification to the normally encountered quasi-static curving force. The second is the impulsive force developed due to the switch entry angle. Whether "switch raise" is used or not, the latter force seems certain to dominate, and the existence of the double effect means that the ride (in the case of a passenger train) will be vitiated anyway.

To sum up so far, we at HBRE think that for all classes of traffic on US railways, AREA should be looking very seriously at the advantages to be gained from using thick webbed switches in place of reinforced. Where due to the nature of the traffic, switch raise is required, thick web switches can be made with this feature, but for fast passenger routes or for the LRT situation switch raise is probably neither necessary nor desirable.

4.3 Crossings

4.3.1 Rail Bound Frogs

One result of Henry Boot's market research which will no doubt give satisfaction to AREA members has been that it is concluded that the rail-bound manganese frog is probably the right answer in US conditions if the main requirement is a long-lasting and economical component for the normal traffic situation in US. From HBRE's point of view of course this is not such good news. We do not ourselves produce Austenitic Manganese Steel (AMS) castings. We also realise that even if we did the economics of producing the necessary patterns, proving the moulding and casting techniques, and testing and trying out the product, against the certainty that no market existed on the Eastern side if the Atlantic would render us unable to compete on price with the product as established in USA. The reasons for our opinion are:

- The rail surrounds to the AMS casting can be welded in to the rest of the turnout.

-The proportions of the AMS casting mean that it has a better chance of being metallurgically perfect than a full length cast frog.

-Since designs are available incorporating ramped wings the concept goes some way at least to eliminating problems with "false flanges"

However we also see problems with the concept:

-It does not completely eliminate problems with "false flanges"

-Because it has so many parts, and there are so many bolts we are convinced that it must be expensive both to fit up and to maintain.

-It will share with all other fixed frogs the tendency to suffer from vibration and batter.

-From observation we can state that Rapid Transit vehicles do not ride as well as they either could or should, over rail bound frogs.

4.3.2 The Alternatives to Rail Bound Frogs.

We at HBRE believe that although perhaps on the general run of moderately trafficked freight lines in North America, there is no need to move away from the conventional rail bound frog, there are situations where something better is required. These situations are:-

(1)on routes where fast passenger traffic shares the metals with heavy axle weight freight traffic.

(2)on exceptionally heavily trafficked freight routes (e.g. the Burlington Northern, where annual tonnages exceed 40 million).

(3)on light passenger routes such as rapid transits.

HBRE believes it can offer frog designs to meet each of these sets of circumstances.

4.3.3 Swing Nose frogs for Fast Passenger and/or Heavy Haul routes.

For these situations we can offer the swing nose frog. It is perhaps worth emphasising at this point that rail bound frogs both in US and Australia seem to have a somewhat comparable life. Mount Newman were getting 120M tonnes whereas we understand Burlington Northern get between 125 and 200M, both undertakings carrying about 40Mte per annum. Mount Newman more than doubled frog life by going to our swing nose design. For US use we recognise that further proving installations may be necessary, to convince users that the design will stand up to the rigours of both the North American winter and of rolling stock with badly hollow worn wheels, but nevertheless we think that doubling of the life

of the frog in conditions of extreme axle loadings and annual carryings is a benefit well worth aiming for.

4.3.4 Welded Vee Frogs for Mass and Light Rapid Transit

For Rapid Transit we are offering a frog incorporating a welded Vee, in a frog otherwise of standard design. The technique of the welded Vee has been developed in UK at Sandiacre over the last 20 years. Basically the process consists in forming a "Vee" from two symmetrically arranged rails suitably machined on their contiguous faces and welded together by the electro-slag process. Each Vee is joined together by two welds, one in the head and the other in the foot. Both welds are done simultaneously with the work piece being held with the longitudinal axis of the Vee held vertically. This both speeds the work and minimises the risk of distortion due to eneven cooling. Following welding the machining of the Vee is completed by planing the outer faces of the Vee in the usual manner, with the significant difference from "Built-up" frog manufacturing practice, that the tip of the Vee is formed from weld metal and not from the parent rail. When machining is completed the Vee is incorporated with wing rails made from plain line rail appropriately machined using blocks and bolts or multi-grooved locking pins. These frogs have been used on BR for more than 10 years and withstand 25te axle-load wagon traffic at 100kph as well as high speed passenger traffic. Although their anticipated life under 25 te Axle loadings may be somewhat less than that of a cast AMS monobloc frog (and for lighter axle loadings the difference is not very significant), they are much cheaper. Not only is the unit cost in series production less but if a non-standard frog angle, or a frog with unusual leg curvature is required, the article can be made by the welded vee technique with none of the on-costs associated with the making and proving of a special pattern and mould. Once in the track the welded vee type frog is easier to handle for maintenance replacement and, (certainly in the UK context) quicker to obtain in an emergency. The welded vee frog is consequently a very popular product amongst engineers in the field situation on BR. HBRE now have facilities for producing welded vees at Dronfield as well as at Sandiacre.

4.3.5 Guard Rails

On BR welded Vees are teamed with guard rails made from plain line rail and secured to the opposite rail by distance blocks and bolts, a practice somewhat similar to that current in US. The railways of Continental Europe have developed the technique of using a specialised guard rail, and this practice has been taken up by many other railways. In our observation this design is a better proposition for maintenance than the conventional type of guard rail since it can more readily be shimmed out to take up wear. It is lighter to handle and being purpose made as a sacrificial element in the system it carries with it a minimum of unusable metal. For these reasons we manufacture and recommend guard rails made from the UIC U69 section secured independently of the opposite rail, with or without tie bars to give check gauge control.

A combination of welded Vee with U69 guard rails would make a cheap and efficient alternative to the rail bound frog for any Rapid Transit system, whether a fully fledged Mass RT undertaking like Singapore or a LRT such as Tuen Mun. For the US market we believe they could be supplied at a cost of about $5000 excluding installation.

5.Summary and Conclusions

Driven by commercial necessity to examine what it has to offer to an unfriendly world, HBRE has seen that there are opportunities for the supply of S & C material to railways in countries which do not at this time possess an appropriate component industry. Such railways mostly are low mileage undertakings and as such although in aggregate a substantial market, they offer individually only small and erratic sales opportunities. Nevertheless the experience gained from these jobs coupled with our continuing involvement with BR, enables us to have a view of the trackwork engineering scene worldwide.

What we see has convinced us that to meet the performance requirement of a modern railway business the track components need to be designed and manufactured to the highest standards consistent with reasonable regard for economy and ease and simplicity of maintenance. To this end HBRE have as international contractors developed the capability to supply high quality S & C components to order, and to contract for installation of complete layouts. In addition however, because of our capability to produce designs "in house", we are able to co-operate with railway administrations in producing designs for new generation turnouts to the performance specification of the undertaking concerned.

In the US context we have come to the conclusion that in some respects S & C could be improved by embracing features of design and manufacture which are now recognised practice in such widely separated parts of the world as UK, Europe, the Middle East and Australia. In particular we believe that the following things could be done, depending on circumstances:

1) For Heavy Haul:

   a) By using thick webbed, high strength rail in place of standard rail with AMS points and reinforcing bars a more economical switch design can be achieved with no loss of security.

   b) Frog performance in high annual tonnage situations can be improved by using swing nose frogs in place of rail-bound frogs at present used.

2) For Rapid Transit

   a) For passenger comfort, maximisation of speed

through turnouts, and economy and security of maintenance, switches made of high strength thick webbed rail with much finer switch entry angles than the present generation of AREA switches should wherever possible be used.

b) The welded Vee frog is offered as an alternative to the rail-bound frog which is cheaper in first cost, has good maintenance properties and is likely to give just as good, if not better smoothness of running.

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Acknowledgement

Considerable reference has been made in preparing this paper, to ref 2 above and also to :

AREA Standard drawings

British Railway Track - Design, Construction and Maintenance
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The Permanent Way Institution, 1979

TABLE I

COMPARISON OF MACHINING OPERATIONS ON NORMAL AND THICK WEBBED SECTION SWITCH AND STOCK RAILS

Rail	Part of rail	Normal Section	Thick web Section
Stock	Head	1 cut to chamfer	1 cut to chamfer
	Foot	1 cut to clear switch foot	No cut
Switch	Head	Cuts to both sides to form running face and chamfer	
	Foot	1 long cut to clear stock rail foot	1 short cut required on stock rail side if symmetrical. (almost no cut if asymmetrical)

TABLE IV

ECONOMICS OF SWING NOSE CROSSINGS
(Source: Mt Newman Railroad, Western Australia)

Item	Swing Nose Crossing First Cost	Swing Nose Crossing Life Yrs	Swing Nose Crossing Annual Cost	Railbound Mn Crossing First Cost	Railbound Mn Crossing Life Yrs	Railbound Mn Crossing Annual Cost
Basic Frog Assembly	14997	7	2142	8488	3	2829
Baseplates	2000	14	143	2000	12	167
Guard Rails				4355	4	1089
Switch Machine	7000	14	500			
Maintenance Costs						
Replacement*			515			1245
Weld & Grind			609			1471
Lift & Pack			1425			1845
Lubrication			296			-

TOTAL ANNUAL SAVING PER CROSSING.................3016

*This item covers the possibility of a failure of a crossing in service.

Note: 1) This assessment was made prior to installation. Following experience MNRR modified their assessment of the anticipated life to 10 years and this results in the above figure being modified to $A4321.

2) All Costs are quoted in Australian Dollars. $A1 = $US0.686

TABLE V

COMPARISON OF NATURAL ANGLE TURNOUTS
AREA vs BR

NOTE: Switch Detail 4000 quoted in each case.

Frog No	Origin	Radii Turnout	Radii Switch	Radii Planing	Lead	Switch	Entry Angle
8	AREA	167.87	163.33		17.96	13'0"	1 30'30"
	BR	184.00	184.00	230.70	21.47	BV	0 42'40"
9.25	BR	245.75	245.75	287.25	25.03	CV	0 31'11"
10.75	BR	331.70	331.70	367.05	29.35	DV	0 21'56"
12	AREA	367.29	328.59		26.61	19'6"	0 57'04"
15	BR	762.00	645.10	739.7	41.75	EV	0 19'23"
	AREA	609.813	Straight Switch		40.05	30'0"	0 58'30"
16	AREA	683.01	652.28		36.09	26'0"	0 45'14"
	BR	645.1	645 1	739.7	41.75	EV	0 19'23"
18.5	BR	980.9	980.9	1137.05	50.11	FV	0 15'14"
	AREA	1002.58	Straight Switch		46 32	30'0"	0 58'30"
20	AREA	1014.99	1000.36		47.56	39'0"	0 23'39"
21	BR	1263.75	1263.75	1398.50	57.33	SGV	0 11'14"
24	BR	1650.40	1650.40	1826.30	65.53	GV	0 09'50"

TABLE VI

COMPARISON OF SWITCH DETAILS
AREA vs BR

Switch	Entry Angle	Planed Length	Heel Length	Switch Length	Radius Planing	Radius Switch
11ft	2 39'34"	1.485	3.353	3.353	Straight	
13ft	2 54'00"	1.266	3.962	3.962		163.135
16'6"	1 46'22"	2.229	5.029	5.029	Straight	
19'6"	1 59'15"	1.841	5.944	5.946		328.587
22ft	1 19'46"	2.973	6.706	6.706	Straight	
26ft	0 45'14"	4.211	7.925	7.925		652.280
BV	0 42'40"	3.500	8.737	10.310	230.925	184.012
30ft	0 58'30"	4.050	9.144	9.144	Straight	
CV	0 31'11"	4.250	11 920	13.860	287.250	245.767
39ft	0 23'39"	6.735	11.887	11.887		1000.36
DV	0 21'56"	5.200	12.440	13.860	367.038	331.687
EV	0 19'23"	7.000	17.257	17.485	739.696	645.116
FV	0 15'14"	8.500	20.807	17.485	1137.067	980.920
SGV	0 11'14"	10.150	24.357	17.485	1389.518	1263.740
GV	0 9'50"	11.600	27.904	22.455	1826.293	1650.380

Note: AREA switches quoted by length, BR by letter code.
Planed lengths for AREA switches calculated.

Ballast Stabilization to Remove Slow Orders after Track Work on Amtrak

G. E. Ellis*

Presentation to 1986
AREA Technical Conference
Chicago, Illinois, March 25, 1986

Amtrak is an operating railroad providing rail passenger transportation in the major inter-city travel markets of the United States and, in particular, in the Northeast Corridor. The Corridor traverses 456 route miles from Washington, D.C. to Boston, Massachusetts, of which Amtrak owns and operates 363 miles.

This Corridor is the most heavily traveled inter-city rail passenger route in the United States. In addition to accommodating the inter-city high speed passenger traffic, the Corridor also carries long distance passenger trains, connects with short distance feeder services, and is used extensively by freight, including heavy unit trains and, of course, the commuter services in and around the large metropolitan areas. Because traffic levels are high, maintenance activities must be carefully planned and scheduled to avoid service disruptions.

In addition to avoiding service disruptions, we must also provide good ride quality. Ride quality, as perceived by the passenger, is a function of track geometry, vehicle suspension characteristics and train speeds. Since a primary goal of Amtrak is to reduce station-to-station trip times, our track quality must be improved to provide these higher speeds. In summary, our mandate is to provide a safe, comfortable and on-time service to our patrons in the Northeast Corridor.

There is a time loss of 3 to 4 minutes because of a diversion through one block or slowing from a 120 M.P.H. maximum authorized speed to 30 M.P.H. through the work area. This is a typical slow order caused by maintenance operations. Between New York and Washington, in any one day, we could have as many as four or more slow orders resulting from maintenance operations. As you can see, this is unacceptable if we are to maintain our on-time commitment to our passengers.

Safety, particularly the safety of our passengers, is the Number One priority at Amtrak. As all of you know, maintenance operations, primarily lining and surfacing, effect the stability of the track and is a serious concern to every railroad, especially since the introduction of continuous welded rail. The primary concern at Amtrak is the behavior of the track after maintenance work has been carried out, especially in regard to track geometry.

High Speed Surfacing and Accompanying Speed Restrictions

An automatic reduction from maximum authorized speed to a reduced speed, generally 30 M.P.H., is imposed for protection against substandard track conditions, such as rail anchor patterns, substandard ballast conditions, missing fasteners on concrete tie track, or a disturbed condition of the track structure. A general speed restriction of 80 M.P.H. goes into effect and suspension of work is imposed during periods of extreme heat when air temperatures are expected to be 95 degrees or above during a twenty-four hour period. Further, the following work will be suspended when air temperatures are expected to exceed 95 degrees:

High speed surfacing
Smoothing — less than 5 ties disturbed
(from 11 A.M. to 8 P.M.)
Tie renewals (except under continuous track outage)

These restrictions increase our station-to-station time and increase the percentage of late arrivals and cause our passenger delays and missed connections.

*Assistant Vice President — Chief Engineer, National Railroad Passenger Corporation (AMTRAK)

Explorations for Alternatives

Because of the impact these slow orders have on our operations, Amtrak Engineering undertook an examination of the maintenance practices of other railroads, both domestic and foreign. We found that, for the most part, the railroads on the North American continent, primarily concerned with the movement of freight, use consolidation of the track structure under traffic to return stability to track after maintenance operations. On the other hand, European countries, who use rail extensively for inter-city passenger transportation, are faced with similar problems as Amtrak and are actively searching for alternatives to slow orders.

We also undertook an extensive literature search to examine the work performed on the lateral stability of track. This search indicated that a great deal of work has been performed and essentially reflected the application of Euler's formula on column buckling as it would apply to track laid in ballast. Buckling rates could be accurately predicted given measurable values on all conditions. However, Amtrak's problem with this approach was that it was highly theoretical and assumed all conditions in the field are controlled. As all of you know, tremendous variances in track construction and support can occur in very short lengths. In addition, we have the destabilizing effect of moving loads with high impacts and high lateral forces. These contribute to a weakening of the track structure and are not adequately duplicated in the laboratory or in field tests.

In earlier attempts to stabilize the track after surfacing, we have even resorted to moving loaded ballast trains over the work area to develop sufficient train tonnage for stabilization in a short period of time. As I am sure you will all appreciate, this is time consuming and expensive.

We also approached the U.S. Department of Transportation, Federal Railway Administration — Office of Research and Development, for information. We have found that a great deal of work is underway to identify the problems of lateral track stability under traffic. We would like to take this opportunity to publicly thank Messrs. Lou Thompson and Howard Moody for their assistance in developing this information.

We are also deeply indebted to the work performed by the Transportation Systems Center located in Cambridge, Massachusetts. Our special thanks goes to Messrs. Sluz and Kish and members of their staffs for assisting us in this investigation.

As noted earlier in our investigation of practices on other railroads, we learned that lateral instability is a more serious problem on European railroads where the traffic is as frequent as that which we experience, but where the axle loads are lighter and the weight rail used is generally less than that used in this country. This requires the period of ballast reconsolidation under traffic to be much longer than for track in this country which carries heavy freight tonnage and is constructed of heavier materials. The foreign properties, therefore, are paying increased attention to reconsolidation of ballast after track maintenance work. Machinery has been developed in an attempt to shorten the time required to reconsolidate the ballast and restore track stability. Our review of European experiences, although operating with different conditions of traffic and track construction, indicated to us that the use of ballast consolidating equipment had a potentially valuable role in the maintenance operation on the Northeast Corridor.

Stabilizer

Based on this review, Amtrak dispatched Mr. J. J. Hannaford, Senior Director — Engineering Equipment, to Europe during October of 1983, to review the equipment and practices in use and to make recommendations for our consideration. It was Mr. Hannaford's recommendation that Amtrak secure a Plasser dynamic stabilizer for testing on the Northeast Corridor. This machine was delivered to Amtrak in late 1983. Amtrak has undertaken extensive testing under various conditions since that time.

Testing

Several physical conditions were tested by determining the lateral resistance of vertically unloaded track. Amtrak Engineering focused their attention on the following questions:

1. What is the difference in lateral resistance of concrete tie track that has not been disturbed, track that had been surfaced only, or had been surfaced and consolidated, utilizing the Jackson Ballast Compactor or the Plasser Stabilizer?

2. To what degree can mechanical ballast consolidation restore lateral track resistance when applied immediately after track surfacing?

3. How rapid is the recovery of lateral track resistance after surfacing under the exposure of Corridor traffic?

4. Is there a detrimental affect on concrete tie inserts, insulators, clips, timber ties, plates and cut spikes?

In order to develop data on lateral track stability several testing procedures were used. The first test consisted of measuring the lateral resistance of a single tie.

Single Tie Test

This consisted of uncoupling the concrete tie from the track by removing the clips and insulators and elevating the rail to eliminate base friction. A line was secured to the concrete tie shoulder insert and this, in turn, was connected to a hydraulically operated hand pump for applying pressure. This was then connected to a dynamometer with a direct reading pressure dial and was secured to a fixed object, usually a bulldozer, located on the shoulder of the track.

On the opposite end of the tie, a steel plate was secured to the shoulder of the tie and a displacement dial indicator was positioned against the adjacent rail. As the tie was moved to the shoulder, readings of the amount of force required were taken and recorded at 2mm and 4mm movements.

This procedure was followed in undisturbed track, track that had been surfaced, track that had been surfaced and consolidated, and track that had traffic on it for 24 hours, 48 hours, and seven days.

Test Results

The results indicated that maintenance operations on track reduced lateral resistance by about 40% to 50% and that compaction and consolidation would improve this figure by about 10% to 15%. Also, we found that the restoration of track stability under traffic to its full lateral strength was a slow and often erratic process.

A second method of testing was adopted which we call the panel system. A panel consisted of twenty (20) clusters of twenty (20) ties each in the tangent and curve sections. Tie displacement was made with a Plasser Roadmaster tamper, with additional instrumentation as follows:

This system was adopted from European practice and you will also notice that the rail was not isolated from the adjacent track structure. Therefore, torsional resistance of the rail and the differing temperature effect of rail impacted on the readings of lateral resistance in these tests. Because the climatic conditions were relatively uniform, each test starting with undisturbed track and continuing through 48 hours after tamping was useful, but comparisons between the several test sites cannot be made because of temperature and torsional differences.

Test Results

The lateral stability readings were measured on undisturbed track: immediately after surfacing, twenty-four (24) hours after surfacing with twelve (12) trains, and forty-eight (48) hours after surfacing with whatever traffic was available.

Tests on curved concrete tied track indicate that the lateral resistance response of the track structure

Change 50 ties an hour under heavy traffic

Twenty trains per day use this track. Yet despite this heavy traffic, a single MRT-2 Tie Changer can replace 50 ties an hour in an average day. The secret is the quick on-off track ability designed into the MRT-2. In less than two minutes, any place along the line, it can climb on or off track completely under its own power. Old ties - even switch ties - are removed whole, with minimal disturbance to track structure.

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is similar to that of the tangents and, therefore, the application of the conclusions are applicable to both tangent and curved track.

Timber Tie Test

The tests on timber ties was a supplement to the concrete tie test to determine if there is similar behavior in the surfacing and restoration of track stability with that of the concrete tie track. Here, again, the test was to be conducted on tangent and curved track. The initial tests for the tangent track indicated a proper comparison, albeit the timber ties indicated a lower lateral resistance.

When the same panel testing was conducted on the curve with timber ties, it was noted that the tamper-liner reached its maximum displacement before 4mm lateral movement in the tie could be recorded. We then measured the movement of the base of the rail and the ball of the rail, since the liner is pushing on the rail and not the tie. We discovered that we were experiencing a movement of from 1 1/2mm to 3mm in rolling of the rail or taking up manufacturing tolerance in the tie plates.

Timber Tie Construction

To eliminate this problem, a prototype track construction was undertaken using a self-tapping screw spike to secure the plate firmly to the tie and to use a pandrol clip-on shoulder and E-clip to secure the rail to the plate. This prototype effectively eliminated movement of the rail in the plates. Tests were then conducted on tangent and curved track.

It was on this test that the Transportation System Center Research and Special Programs Administration conducted their track lateral resistance tests at the request of Amtrak. The purpose here was to confirm results obtained by the Tamper liner for measuring lateral resistance. The comparisons have been very good and the conclusions were similar.

Results and Comparisons

In summary, these tests indicate the required lateral stability to maintain an adequate margin of safety depends on the neutral temperature of the rail, maximum potential rail temperature, the amount of misalignment in track, the degree of curvature and other less influential factors, including track structure (i.e. rail weight and tie weight), and track longitudinal stiffness. On this last item, as demonstrated on our timber tie tests, with conventional cut spikes and rail anchors, we found that the longitudinal stiffness of wooden tie track was not adequate for our purpose. Engineering decided not to change the speed and operating restrictions on timber tie track.

Further, it was found that there was no detrimental effect on concrete tie inserts, insulators or clips. The conclusions derived from these tests are:

Test Observations

- Concrete tied track consolidation by a dynamic stabilizer improved track lateral stability by about 10% to 15% over track that had been tamped only and *raised* without consolidation. A compactor also improved track lateral stability from 8% to 10% over track that had been tamped and *raised* without consolidation.

- Measured results using single tie tests and panel tests on Corridor track appears to agree closely with previous test results on other railroads and at FAST.

- 73,000 tons of traffic in the forty-eight (48) hour period of the test increased the lateral resistance of tamped track by about 11%.

FORMULATION OF AN EXISTING POLICY FOR HIGH SPEED SURFACING

In the past, we imposed a speed restriction of 30 M.P.H. for the first twelve (12) trains in a twenty-four (24) hour period. Since it was demonstrated that the use of compaction or stabilization increased our lateral track resistance to the same degree as 48 hours of traffic, we have formulated a new policy covering high speed surfacing as follows:

For track which has been surfaced and has been treated immediately with compacting equipment, a slow release policy will be as follows:

1. First train at 30 M.P.H. over the area.

2. Walking inspection by the involved supervisor to assure no deficiencies (i.e., misalignments, standard ballast section, anchoring, etc.) exist that would adversely affect the safe passage of a train.

3. Sixty (60) M.P.H. for a twenty-four (24) hour period and the passage of twelve (12) trains.

4. After 3 above, the track may be returned to maximum authorized speed.

Evaluation of Concrete Turnout Ties and Bridge Ties

J. F. Scott*

Presentation to 1986
A.R.E.A. Technical Conference
Chicago, Illinois, March 26, 1986

ABSTRACT

Canadian National Railways now have roughly 2-1/2 million concrete ties installed in track, and are currently evaluating the merits of concrete turnout ties and concrete bridge ties. Field measurements have clearly demonstrated that impact loading from wheel tread defects presents the greatest obstacle to more economical concrete tie design. The concrete tie being a designed element, is eminently suited for performance evaluation through strain gauge mesurements. Similar measurements have not been taken on wood ties, and they have simply been replaced when they split, rotted, became severely plate cut, or spike killed. It is believed that the loading which can cause distress in concrete ties has for years been also causing distress on wood tie track. It is suggested that A.A.R. Interchange Rule No. 41, Section A, Cause for Wheel Renewal, be amended by including wheel loading exception limits. It is also suggested that a train full of non-condemnable wheel tread defects be run on the FAST track to establish the costs associated with accelerated rates of track degradation.

INTRODUCTION

This report is divided into four sections:

1. Concrete turnout ties
2. Concrete bridge ties
3. North American Wheel/Rail Loading
4. General Conclusions

Before getting into details, I would like to give you a brief history of concrete track ties on Canadian National Railways. The first records we have found date back to 1922, and during the 1920's a number of small test installations of concrete ties were made in the Lakehead area. Some of these ties failed rather quickly, while other small pockets of ties remained in track until 1941. In the fall of 1961, 1000 French type RS two-block concrete ties and 800 A.A.R. Type E or MR ties, also known as AREA Mark I, were installed on the Drummondville Subdivision in Quebec. From 1965 to 1967, a number of small test installations of British Rail Type F-23 and F-27 ties, Swedish Type 101 ties, French Type RS, and Canadian-made Types A, B, and C were installed at various locations. From these test installations, it became apparent that the British Rail Type F-23 concrete tie with Pandrol rail fastening system provided the most maintenance-free track structure, and in 1972, CN installed roughly 10,000 Costain U.K. Type F-23 ties modified slightly for Canadian conditions, on a 4-mile section of track west of Jasper, Alberta. In 1973, an order was placed for 300,000 CN60A concrete ties, and this was followed in 1975 by a separate order for 1.5 million concrete ties. In 1981, the CN60A tie design was refined into the CN60B. CN now has roughly 2.5 million concrete track ties installed in British Columbia and northern Ontario. Current standards state that concrete ties should be considered on mainline track curves 2° and over, and on tangents up to one mile in length between such curves, where annual tonnage exceeds 20 MGT, and where a significant portion of traffic is carried in 100-ton cars.

*Senior Research Engineer, Canadian National Railways

On this concrete tie territory, all turnouts were still laid on wood ties, and all bridges, with the exception of a few new short spans which were installed with ballasted decks, had wooden bridge timbers. Turnouts require maintenance and wooden bridge timbers burn. In July, 1984, CN made its first concrete turnout tie test installation, and in September, 1984, it made its first concrete bridge tie test installation. This report deals with tie structural performance evaluation. Economics are not covered at this stage, because if the ties do not perform, there are no economics.

1. CONCRETE TURNOUT TIES

The CN Engineering Department prepared drawings for a No. 20 lateral turnout, with 58'-10" power operated Samson point switch, uniform riser design, all-welded 136 lb. R.E. rail, and R.B.M. frog. The order for manufacture of concrete turnout ties was placed with Genstar Costain Concrete Tie Co. Ltd. of Edmonton, Alberta. The concrete tie turnout was installed at Kissick, Mile 9.3 Ashcroft Subdivision, west of Kamloops, British Columbia. Track zone speed at this location was 35 mph.

In the turnout, there are 119 ties with spacings ranging from 1'-7" to 2'-0". With the exception of two ties placed ahead of the point of switch, each tie is unique, and they must fit together like a large mechano set. In order to check on both the drawings and the manufactured ties, the turnout was preassembled at the tie plant in Edmonton. Two ties had to be remanufactured.

The turnout uses the Pandrol rail fastening system with 9 mm thick EVA pads throughout. Switch point and frog plates were secured with screw spikes tightened into threaded nylon ferrules cast in the ties.

The ties are 9-1/2 in. deep, 10 in. wide at top, and 11-1/4 in. wide at bottom. They are prestressed with twelve 3/8 in. diameter indented strand, grade 270, and have static moment capacities of 391 in.-kips in positive or downward bending and 293 in.-kips in negative or upward bending.

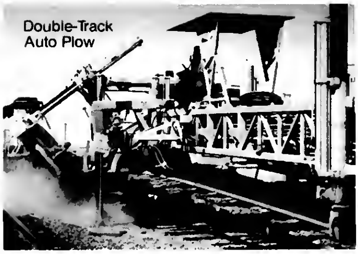
The turnout was preassembled at trackside, and moved laterally into position with a system including six hydraulic jacking units called PUMS manufactured by the Geismar Corporation in France. Old ballast had been removed, a filter fabric was laid, and a layer of new ballast was placed prior to moving the turnout. Complete removal of the old wood tie turnout and installation of the 77 meter long, 100 tonne, concrete tie turnout assembly was accomplished within a 10-hour work block.

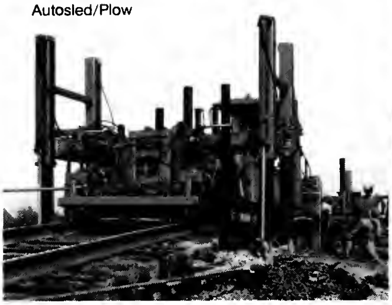
While the concrete ties were still in the Edmonton manufacturing plant CN Research strain gauged six of them. The preselected ties are listed.

Tie T-1	At Switch Points	4 circuits
Tie ST-024	At Heel of Switch	2 circuits
Tie ST-049	On Closure, near Insulated Joint	2 circuits
Tie ST-083	At Point of Frog	2 circuits
Tie ST-087	At Heel of Frog	2 circuits
Tie ST-113	17-ft. Long Divergence Tie	6 circuits

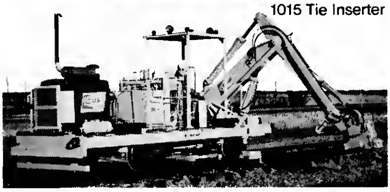
One spare tie was shipped to the Research Labs in Montreal where it was strain gauged and calibrated in order that the field measured strains could be interpreted directly in terms of structural performance safety factors.


Shoulder Ballast Cleaner


Double-Track Auto Plow


Autosled/Plow


Loram's LRT Rail Grinder


1015 Tie Inserter


SP-88 Rail Grinder

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It has been established on CN and other roads that impact loading from wheel tread defects governs the design of concrete track ties. This also applies to turnout ties, but there could be additional impact loading at switch points and point and heel of frog. Ties on the closure portion of turnout between switch and frog have an inherent center bound condition. There was also some concern that the unloaded ends of the long divergence ties might flap up and down while trains were running over the other ends.

Data from ties was recorded for a total of 46 freight trains running at speeds from 19 to 42 mph, and none of the measured strains were of sufficient magnitude to overcome the prestress and put the concrete into tension. It was therefore concluded that the ties should not develop fatigue cracking and there was no requirement to make the ties any stronger. It was also concluded that the ties should not be made weaker in design, as the peak strain in negative bending was at 80% of available pre-compression, and peak strain in positive bending was at 97% of available precompression. At strain levels such as these, the concrete ties could survive many millions of loading cycles without cracking. It is not possible, however, to rigorously define tie safety factors because that depends upon an ill-defined and partially uncontrollable incidence of wheel tread defects.

The best way to gain an appreciation of wheel impact loading is to look at some chart samples. Figure No. 1 shows concrete strains recorded under a loaded coal train running at 32 mph over the turnout. Strain levels were quite nominal on ties at the point and heel of switch, but two large impact loads were recorded on the tie under point of frog. The peak impact factor was 177%. At the heel of frog, every wheel generated impact loading because of the joint. On the 17 ft. long divergence tie, the strain levels were very low.

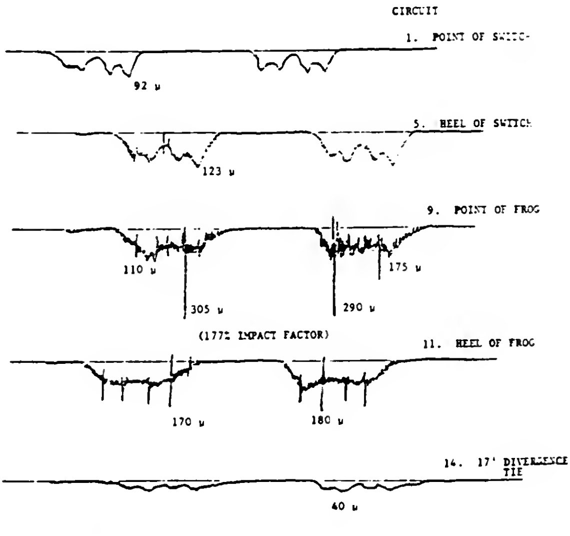


FIGURE NO. 1 - SAMPLE TIE STRAINS UNDER LOADED 100 TON COAL CARS RUNNING AT 32 MPH ON TURNOUT.

In Figure No. 2, the tie under the heel of switch was hammered with 175% impact factor from some unidentified wheel tread defect. The joint at heel of frog generated impact loading from each passing wheel, but strains were lower than those generated by the wheel tread defect. None of the strain levels shown in Figures No. 1 and 2 were of sufficient magnitude to fatigue crack the ties, even if similar strains were applied many millions of times. In all cases, the concrete was still under pre-compression.

While no rigorous statistical analysis of strain levels has been done at this time, preliminary analysis revealed that 0.23 to 0.31% of the wheels generated impact loading on the ties. This might mean that there were tread defects on 0.75 to 1.0% of the wheels, as any one tie would tend to miss roughly two-thirds of the impacts along the track. At the point of frog, the incidence of impact loading was roughly 2-1/2 times greater than on other ties. It is believed, but not confirmed, that this higher incidence was due to hollow tread or "false flange" wheels, which would ride up on the false flange and then drop down to the hollow tread as they traversed the frog.

It is clear that concrete ties do not like rail joints as every wheel generated impact loading. While these loadings were not as large as those generated by wheel tread defects, there would be definite advantages in welding the manganese frog rails to the regular rails.

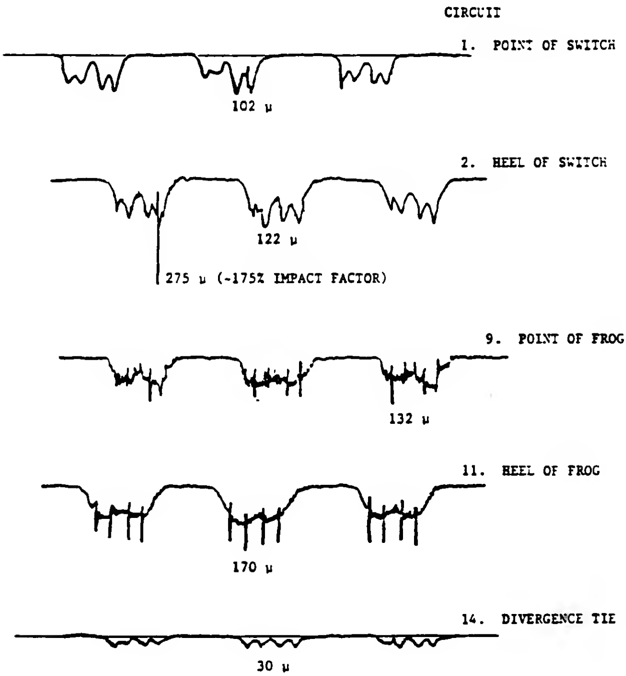


FIGURE NO. 2 - SAMPLE TIE STRAINS UNDER LOADED 100 TON COAL CARS RUNNING AT 28 MPH ON TURNOUT.

The strain gauge evaluation work looked only at the structural integrity of the concrete ties themselves. As the turnout components suffer wear, concrete ties, switch points, frog point, frog heel joint, rail tie pads, spring clips, insulators, nylon ferrules, and tightness of threaded fasteners will be closely inspected. Since July 1984, a minor amount of surfacing and switch point and frog grinding has had to be done. The test installation is still under observation, and no further concrete tie turnouts have been ordered at this time.

The Florida East Coast Railway in 1984 installed a No. 10 concrete tie turnout, with ties manufactured by Railroad Concrete Crosstie Corporation, a subsidiary of the railway. The turnout is installed on non-signalled 15 mph track at a yard entrance in Jacksonville. The performance of concrete ties and turnout components is still being evaluated.

2. CONCRETE BRIDGE TIES

Softwood bridge ties last an average of 15 to 25 years depending on traffic and track curvature. There is always the risk of fire, and in some cases it can cause major disruptions to traffic. Concrete bridge ties offered the possibility of reduced tie maintenance, extended life, and elimination of fire hazard.

In the late 1970's, the Canadian Prestressed Concrete Institute established a liaison committee aimed at promoting the use of precast prestressed concrete on Canadian railroads. In early discussions, it was decided that one of the areas of interest was the development of a prestressed concrete bridge tie. Engineering departments in CN and CP each prepared design drawings for ties, and the liaison committee drew up specifications for rigorous laboratory testing. CN Research was asked if they could conduct the tests, but declined on account of heavy existing workloads. The laboratory research work was subsequently funnelled into Queen's and McGill Universities. Grants for the work were obtained from the National Sciences and Engineering Research Council, and the Transportation Development Centre of Transport Canada was brought in for technical review. Within a period of three years, a great amount of research had been conducted and three masters students theses had been written. The co-operative effort between industry, railroads, universities, and government agencies produced excellent results in record time. At McGill University, the program has been extended, and one of the students is working toward his doctoral degree on the effects of impact loading on the concrete tie/bridge girder system.

In the laboratory tests, CN had two ties under evaluation - one was designed for an impact factor of 60% as suggested in the concrete railway bridge code, and one was designed for 150% impact factor as suggested in the AREA manual for concrete track ties. After evaluating the university static and fatigue test results, CN opted to make a test installation with the lighter of the two ties.

These ties were 12 ft. in length, 12 in. deep, 10 in. wide at top, and 12 in. wide at bottom. They were prestressed with thirty-two 5 mm diameter indented wires to provide a static moment capacity without cracking of 640 in.-kips in positive downward bending and 240 in.-kips in negative upward bending. Design was based on steel bridge girder support spacing of 8'-0", Cooper E80 loading, and one-third of axle loading plus 60% impact factor being carried by each tie. Tie spacing was to be 16 in. center to center.

Twenty-two ties were installed in September 1984 on a short span bridge roughly 50 miles east of Montreal. This was in wood tie territory where freight speeds were 60 mph and passenger speeds were 80 mph. Installation was completed during a work block from midnight to 7 a.m., and an on-schedule passenger train crossed the bridge at 20 mph slow order 40 minutes later. During the morning, the wood tie approaches to the bridge were lifted and tamped because the concrete ties were deeper than the old wood ties. The slow order was lifted shortly after noon, and within half an hour a passenger train travelling at 70 mph crossed over the span. Such operation would not have been possible without all the prior research work.

That same day, CN Research started hooking into 44 strain gauge circuits which had previously been installed on 10 of the ties in the laboratory. These circuits had been calibrated to establish the relationships between bending moment and strain. Over the next two weeks, data was recorded from normal traffic, and then a special work train consisting of locomotive, loaded 70-ton ballast car with one slid flat wheelset, empty box car with one slid flat wheelset, and caboose was run over the bridge at incremental speeds from 3 to 60 mph. These two wheelsets were both non-condemnable by current A.A.R. Interchange Rules.

Before presenting data, it is worth pointing out some features of the installation. The original wood ties were in relatively good condition when replaced, but the backwall timbers were plate cut. When the deeper concrete ties were installed, shims were inserted on the backwall timbers which were left in place. At each end of the bridge, 5 longer-than-normal wood ties were installed to act as transition from the relatively soft wood tie track to the stiffer bridge. On the concrete bridge ties, half the rail/tie pads were soft 5 mm thick SBR material, while the other half were hard 5 mm thick EVA material. Ties were secured to girders with hook bolts which ran through ties and padded spacer bars on top. Half of the ties were supported on 1 in. thick hard pads, while the other half were on 1 in. thick soft pads. The hard/soft pads top and bottom were located to give four different combinations. All circuits were recorded with 1.5 KHz bandwidth.

Statistical data analysis from the regular trains has not yet been completed, and it is premature to draw general conclusions. The most revealing data in any event was generated by the slid flat wheels on the work train. On the loaded ballast car, the flat measured 1-1/2 in. in length with a straight edge, but the edges of flat were rounded out to 3 in. total. The wheel was technically non-condemnable.

The first conclusion reached was that the end ties were being loaded two to three times more heavily than the intermediate ties. As shown in Figure No. 3, this occurred even at 2 mph, clearly indicating that the wood backwall and approach ties were not picking up their fair share of load. As shown in Figure No. 4, the slid flat wheel was impacting ties quite severely at 30 mph. Laboratory tests had shown that the ties could be statically cracked at roughly 440 micro-strain, and the field measured strains were clearly higher. No cracks could be detected at the time, but it was predicted that fatigue cracking would occur. Figure No. 5 depicts strain levels at 60 mph. The slid flat only hit the rail every 8-1/2 ft., and it is clear that impact loading was not well distributed along the rail. The tie directly under the impact point was the one that was hammered. The track was responsible for the high strains on the end ties, while the slid flat wheel was responsible for the high strains on the intermediate ties. This is a good example of vehicle/track interaction.

FIGURE NO. 3

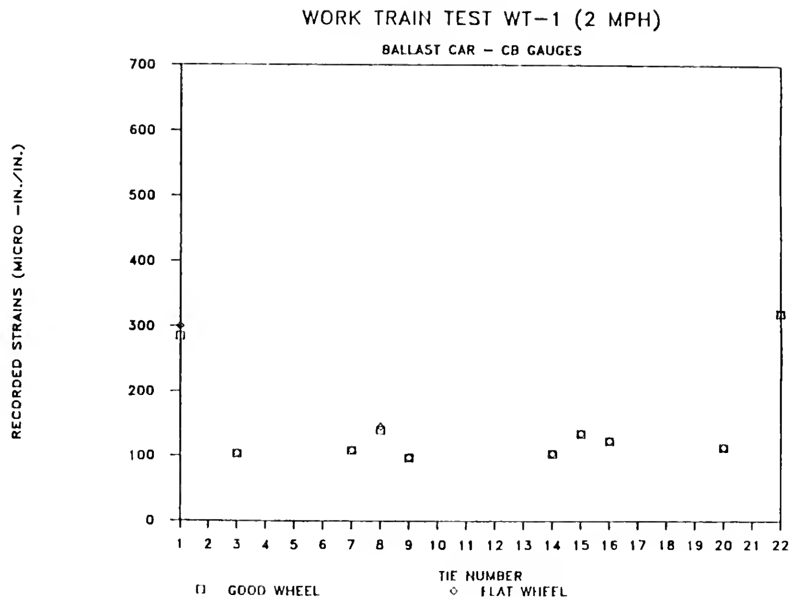
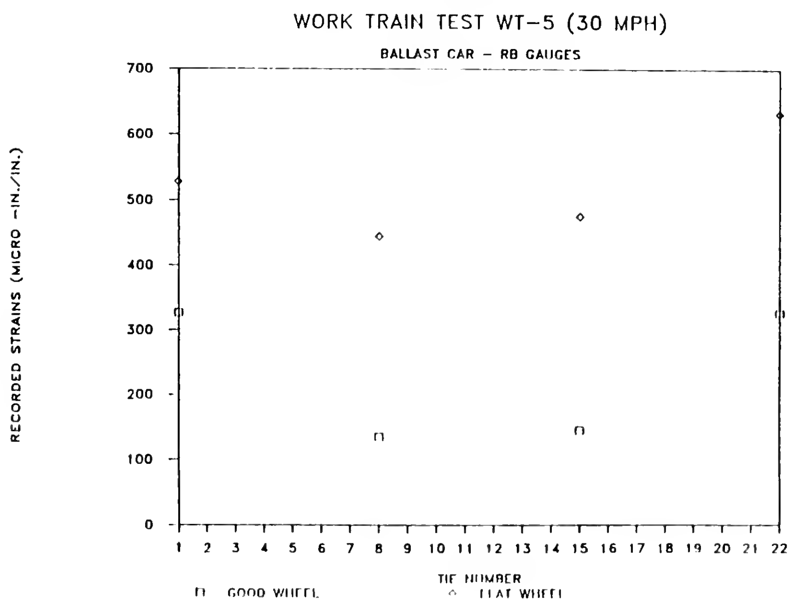
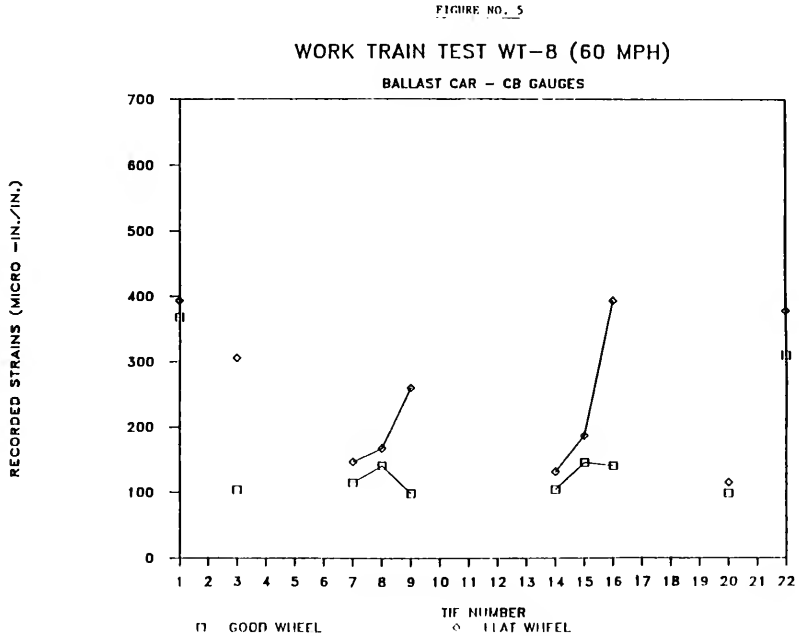


FIGURE NO. 4



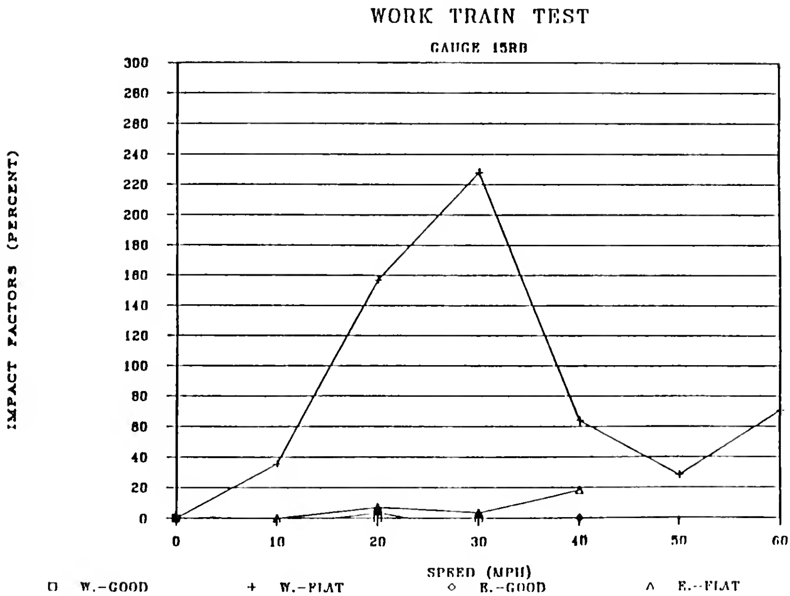


The impact factor of 230% generated by the slid flat wheel at 30 mph is shown in Figure No. 6. It would clearly be a mistake to put a 30 mph slow order on such a car. It is worth noting that the good wheel on the car generated less than 10% impact, and that the flat wheel, when run in the eastward (E) or opposite direction, appeared to generate less than 20% impact. This is more fiction than fact, and resulted from the slid flat shifting position relative to track because of wheel creepage from run to run. Data from isolated measurement points in track must be interpreted with caution.

Sample strain traces from two of the intermediate ties are shown in Figure No. 7. On the top trace, at rail seat on Tie 15, an impact factor of 200% was generated, and it will be noted the tie underwent reverse bending. The problem facing concrete tie designers is very evident.

It had been predicted in September 1984 that the concrete bridge ties would develop fatigue cracks. No cracks were detected at the time, and none were detected in February 1985. In May 1985 both end ties were found to have 4 to 5 cracks each running from tie bottom to mid-depth. No cracks could be detected in the intermediate ties. As there were natural concerns for track safety, one of the spare ties was taken to the Research lab., and subjected to fatigue testing. Results are shown in Figure No. 8. It was cyclically loaded at 88% of the static cracking moment, and after 1.87 million cycles, visible cracks had developed. After 20.3 million cycles, these cracks were virtually unchanged, and loading was increased in increments until it was 45% above the static cracking moment. After a total of 23.6 million cycles, the tie was still carrying load but increasing deflections indicated it was nearing collapse.

FIGURE NO. 6



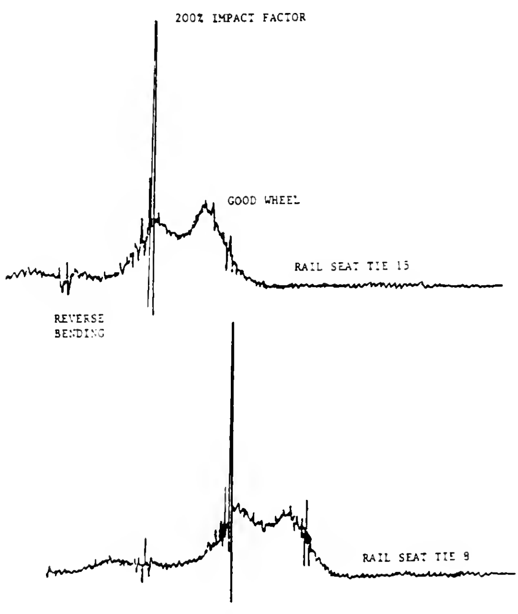


FIGURE NO. 7 - IMPACT STRAINS FROM -1-1/2 IN. SLID FLAT ON LOADED 70 TON CAR AT 30 MPH.

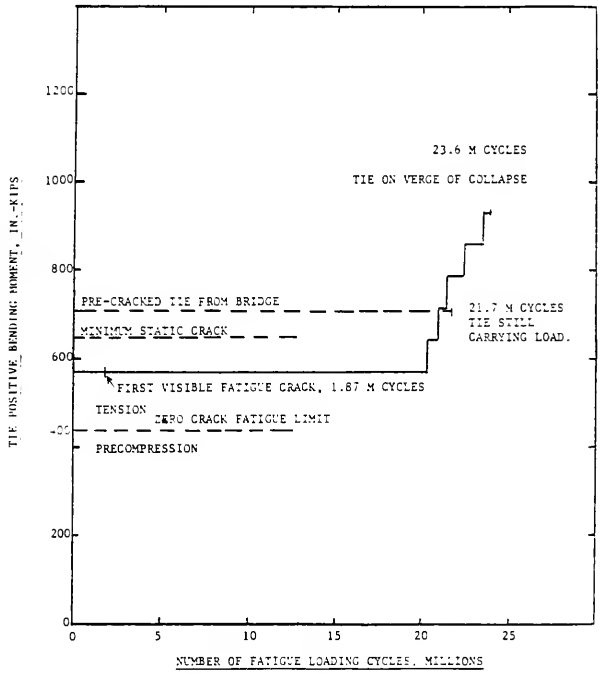


FIGURE NO. 8 - FATIGUE TESTS ON CONCRETE BRIDGE TIES

The bridge end ties were removed and replaced with two uncracked spare ties, and one of the cracked ties was then laboratory fatigue tested. It was loaded to 708 in.-kips moment, or 10% above the static cracking moment, and after 21.7 million cycles, the cracks were virtually unchanged, and the tie was still carrying load with no signs of failure. It is clear that cracked concrete ties can continue carrying load for many millions of cycles. We would prefer zero cracks in order to protect concrete from harsh environmental attack.

During the mid and latter part of 1985, as well as replacing the two cracked end ties, 50 regular CN60B track ties were installed on approaches at each end of the bridge. Twelve longer-than-normal wood ties were installed as transition between wood and concrete tie track. The old backwall timbers were replaced with new timbers, and they were fitted with Pandrol fastenings. To obtain some attenuation of impact loading, 6.5 mm thick studded pads were placed on all the track and bridge tie rail seats. Research will take more measurements this coming May to evaluate the effectiveness of these changes.

CP Rail has also made a trial installation of concrete bridge ties, and they are currently analyzing strain measurement data. Ties were designed for 150% impact factor, and they are larger than CN ties because bridge girder spacing is at 9 ft. rather than 8 ft. Concrete bridge ties on the Florida East Coast Railway are much smaller because bridge girder spacings are 5'-0" or 5'-3". It is simple to design ties for differences in girder spacing, but it is another matter to cope with wheel tread defects.

3. NORTH AMERICAN WHEEL/RAIL LOADING

The "acceptable" limits of wheel tread impact loading in North America are indirectly defined by A.A.R. Interchange Rule No. 41, Section A - Cause for Wheel Renewal. Any railroad interested in cleaning up their own wheels will only be partially successful because of the relatively large numbers of leased and foreign cars that operate on their lines.

In 1947, the A.A.R. conducted a rather extensive series of tests on the effects of impact loading from a slid flat wheel on a 70 ton car. To the author's knowledge, no such testing has been conducted on 100 ton cars.

In order to evaluate current impact loading "standards", CN Research in June 1985 installed a wheel loading measurement system on a tangent section of concrete tie track where speeds were 60 and 80 mph for freight and passenger trains respectively. Five shear strain circuits were located on each rail such that 100% circumferential coverage for both 33 and 36 in. diameter wheels was obtained. A special work train with both empty and loaded 70 and 100 ton cars containing 14 wheelsets with tread defects, none of which were technically condemnable by A.A.R. Rule 41, was run in 5 mph incremental speeds from crawl to 75 mph. A tremendous amount of data was collected, and it is only possible to present a small portion of it here.

Impact factors generated at speed by some of the wheels are shown in Figure No. 9. Wheel No. 5A, on a loaded 100 ton car, had a somewhat innocuous looking shell located at the bottom of a 0.157 in. deep valley spread out over roughly 18 in. of tread circumference. This wheel exceeded the AREA concrete tie design impact factor of 150% at 36 mph, and reached 277% impact factor at 55 mph. Wheel No. 9A, with built-up tread, reached 150% impact factor at 46 mph. The locomotive, with good wheels, never exceeded 42% impact at speeds to 75 mph. It is considered that these wheels are representative of that small but ill-defined population of "bad" wheels that travel at speed every day on the railroads of North America.

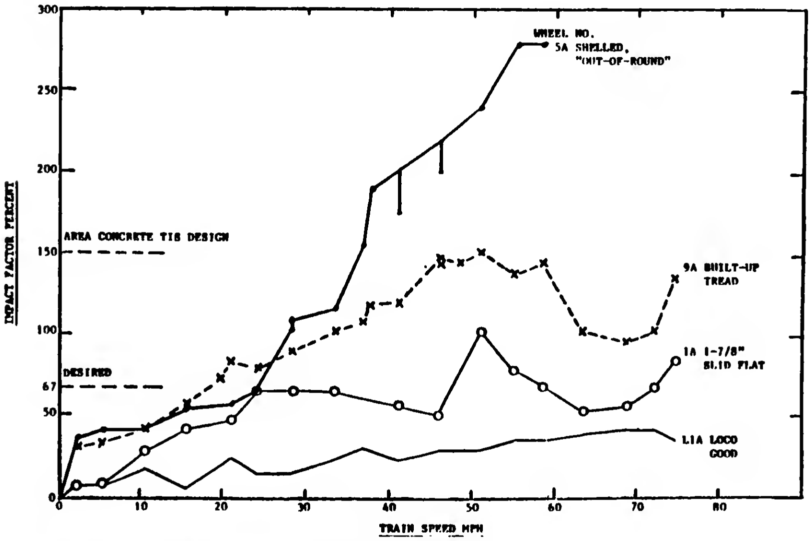


FIGURE NO. 9 - IMPACT FACTORS ON LOADED WHEELS OF 100 TON CARS

The severity of loading is best illustrated by looking at a sample trace of wheel No. 5A running at 55.2 mph (see Figure No. 10). Loading dropped from normal to zero, than rose dramatically to 124 kips. This wheel has been termed the "pile driver". Loading from Wheel No. 9A with built-up tread is shown in Figure No. 11, and this wheel has been termed the "jack hammer". Depending on train speed, this wheel impacted the rail 12 to 30 times per revolution, and generated erratic primary track vibration frequencies ranging from 75 to 150 Hz. If one wished to destroy track structure, he would probably select these two wheelsets for his offensive arsenal. They were both non-condemnable.

THE "PILE DRIVER"

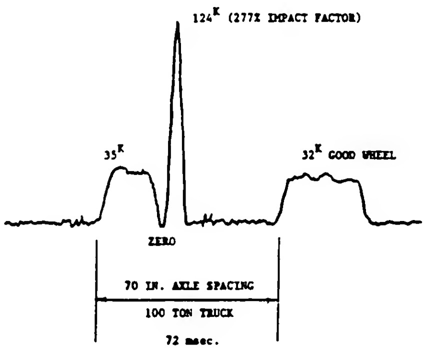


FIGURE NO. 10 - IMPACT LOADING FROM WHEEL NO. 5A AT 55.2 MPH

SHELLED WITH "OUT-OF-ROUND" VALLEY

THE "JACK HAMMER"

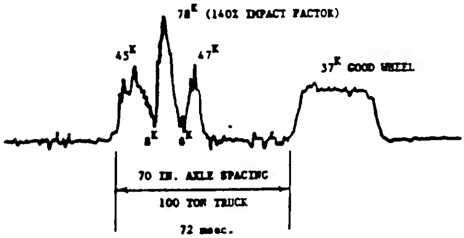
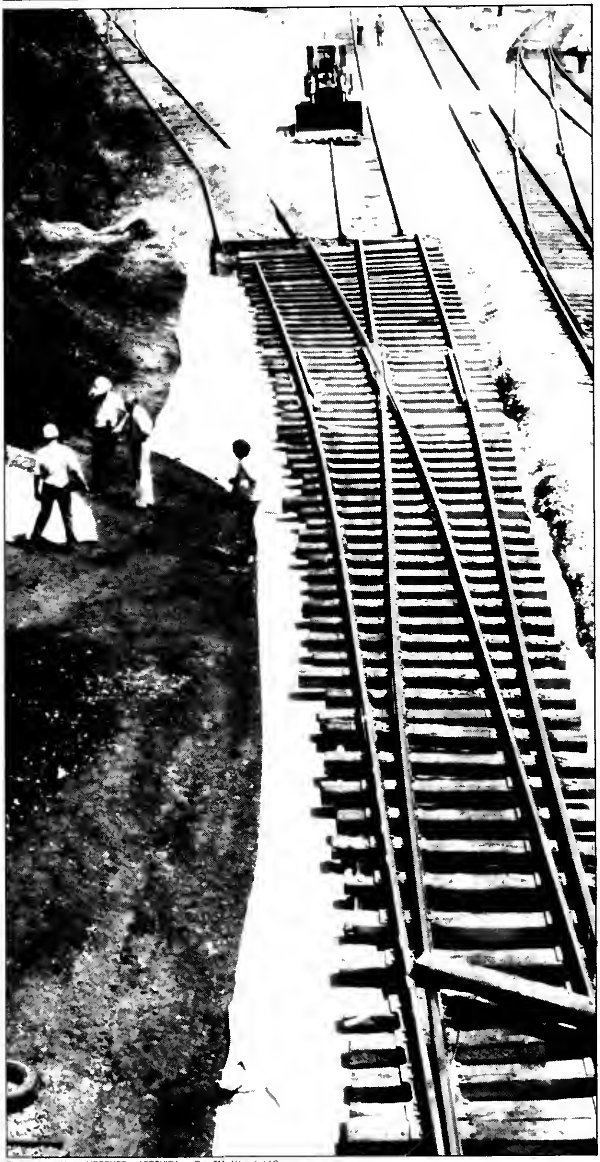
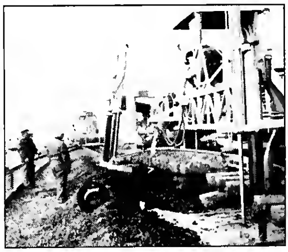


FIGURE NO. 11 - IMPACT LOADING FROM WHEEL NO. 9A AT 55.2 MPH

BUILT-UP TREAD





4. CONCLUSIONS

The design requirements for concrete ties, whether for turnouts, bridges, or track, depend in fair measure upon the impact loads generated by wheel tread defects, and the renewal of such wheels is governed by A.A.R. Interchange Rule No. 41. This Rule should be amended by including wheel loading limits as direct causes for wheel renewal. The intent of the Rule is to protect vehicles, track structure, and train operations, but it cannot adequately do this through use of simple wheel measurement gauges. It is suggested that A.A.R. Interchange Rule No. 41, Section A, be amended as follows:

"Wheel loads exceeding the following limits shall provide cause for wheel renewal, effective on given dates:

"Total Load	Incremental Load	Effective
75 kips	42 kips	January 1, 1987
65 kips	32 kips	January 1, 1989
55 kips	22 kips	January 1, 1991"

For a fully loaded 100 ton car, the 75 kip total load corresponds to an impact factor of 127% and an incremental load of 42 kips over and above the normal static wheel load of 33 kips. The lower total load of 55 kips corresponds to an incremental load of 22 kips and an impact factor of 67%. On our tests with defective wheelsets, the 55 kips loading limit served as an excellent discriminator between good wheels and bad wheels at speeds to 75 mph. Such a limit would avoid fingering out good wheels which were simply reacting to vehicle dynamics. The incremental load limit would form a vital part of the rule, for with proper data manipulation, it would be used to locate bad wheels on all empty and partially loaded cars. The gradual tightening of the rule should prevent sudden overloading in wheel renewal shops.

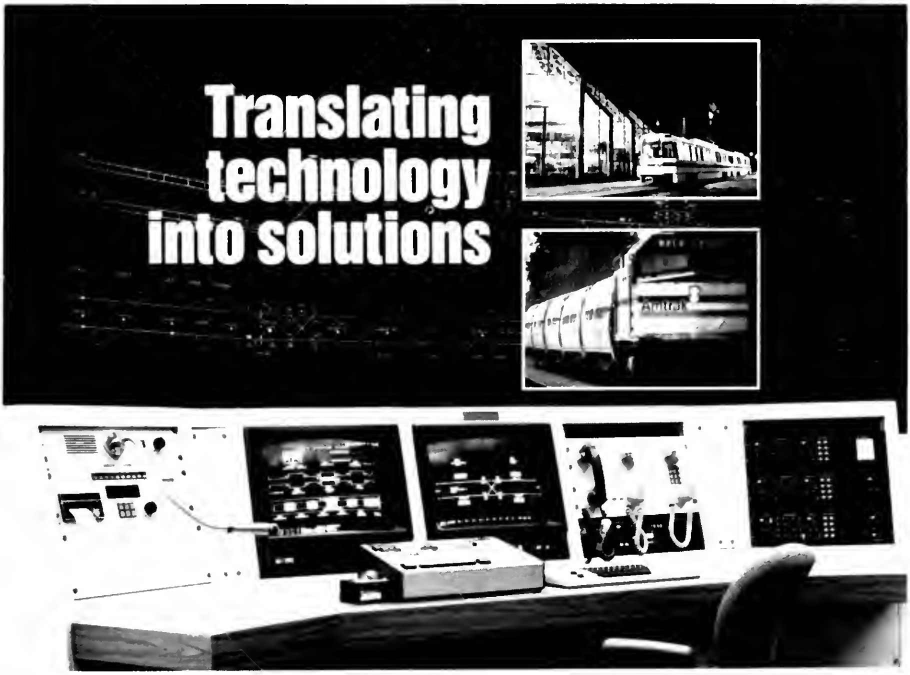
Some of you may already be asking yourselves some questions -- How naive is this guy? Does he not know that industry rules will not be altered until some economics have been developed? I am naive, and I do feel ignorant, because the total costs associated with operation of currently permissible wheel tread defects on North American railroads have never been established. What we have recently measured on concrete tie track has gone unmeasured on wood tie track for years. I believe we have been paying an unhealthy penalty.

I have a suggestion. We should run a train full of non-condemnable wheel tread defects on the FAST track, and fully document rates of rail spalling, concrete tie cracking, wood tie plate cutting, loosening of rail fastening systems, gauge widening, degradation of ballast, roadbed settlement rates, and increases in fuel consumption. The track structure may be destroyed in as little as 20 MGT, but that is exactly the purpose of running an accelerated service test. Very low rates of degradation have already been well documented with good wheels at FAST. Such a test could not be run on revenue lines, but the costs assocated with wheel tread defects could be apportioned to operating railroads based on wheel loading statistics that have been and are being developed for both wood and concrete tie track.

Rail shear strain gauge circuits provide a direct and effective means of detecting bad wheels, and I would recommend them for any railroad concerned with the welfare of their track structure. Gene Sheldon of

Railroad Concrete Crosstie Corporation, a subsidiary of the Florida East Coast Railway, has been kind enough to send me some information from three wheel loading detection stations which were installed over a year ago. Many of the wheels which generated high loadings were found through inspection to be non-condemnable by interchange standards. Such wheels on foreign cars create severe headaches over the problem of how best to get them off the property. From their findings, Mr. Sheldon has concluded that visual inspections of wheels cannot provide for the conditions found by the impact detectors. Rounded-off flat spots, ovate or lumpy wheels are not considered within the interchange rules, and there is no way for an inspector to spot and subsequently gauge for these types of wheel deformities. Rule 41 has to be rewritten in terms of wheel loading exceedence limits. Thank you Mr. Sheldon, my sentiments exactly.

Let me conclude by saying that I am a firm advocate of research aimed at improving railroad productivity. There are some factors, however, that are beyond the scope, and indeed beyond the control, of any individual railroad. The industry must address these factors through co-operative effort. Research is interesting but useless unless it is translated into sound economic action. When we fully understand and can control what is happening today, we can effectively plan for tomorrow.



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Rehabilitation of Belden Tunnel

M. W. C. Emerson* and
V. V. Mudholkar**

Presentation to 1986
AREA Technical Conference
Chicago, Illinois, March 26, 1986

INTRODUCTION

The GTI system provides transportation from Northeast and Canada to the Midwest and beyond using the routes shown in Figure 1. This traffic pattern was developed through the acquisition of several railroad systems which generally had limited their marketing and services within their home states. The routes acquired were generally constructed during or shortly after the Civil War; consequently, the clearances and designs were not compatible with modern railroading requirements. A classic example of this condition was the Belden Tunnel. The tunnel was originally designed for locomotives and freight substantially smaller than loads modern railroads must carry to be economically competitive. Not only was the Belden Tunnel a bottleneck which rendered the GTI system unable to carry some modern freight loads but the location of the bottleneck was such that loads such as tri-level auto carriers and industrial high-and-wide shipments had to be detoured around via the Ninevah Branch. Thus, improving the clearances in the Belden Tunnel was an absolute necessity if the GTI Railroad System were to be improved.

The objective of the rehabilitation project was twofold: to improve clearances to allow the use of high and wide loads on the line, and to improve the structural condition of the tunnel which had been deteriorating rapidly over the recent past.

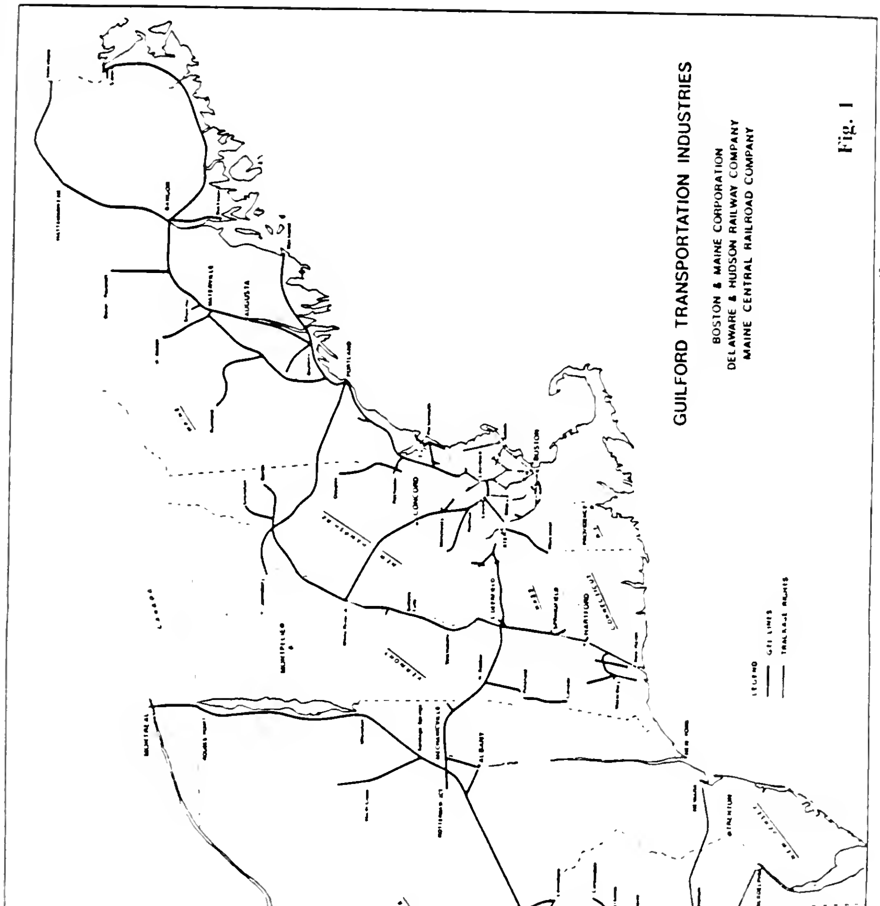
The Delaware & Hudson Railroad (D&H) together with the New York Department of Transportation (NYDOT) had been involved in studies and investigations of the tunnel since 1982 and had conducted preliminary subsurface investigations, seismic investigations and engineering studies prior to the purchase of the D&H by Guilford Transportation Industries, Inc., (GTI) in 1984. Subsequent to that purchase, GTI Chief Engineer Vinay V. Mudholkar was assigned the task of performing the studies necessary to allow proceeding with rehabilitation and enlargement.

HISTORY OF THE BELDEN TUNNEL

The original construction of the Belden Tunnel commenced in the spring of 1864 with the excavation of a shaft at the west portal. The workmen and their families chose to settle at this location and the Town of Tunnel, New York, was born. The tunnel was completed in March 1869. The completion of the tunnel and the establishment of the rail link between Albany and Binghamton gave rise to a struggle for control of the railroad line which ended in a pitched battle.

The Erie Railroad, under the control of Jay Gould and Jim Fisk, sought control of the Albany and Susquehanna Railroad, which controlled the lines from Albany to Binghamton. Fisk, et al., gathered toughs from the Erie RR and started east from Binghamton toward Albany, taking possession of the line as he travelled. Joseph H. Ramsey, President of the A&S RR, mustered his forces and

*Consultant, Foundation Engineering Systems, Inc.
**Chief Engineer, Guilford Transportation Industries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MONTPELIER
ALBANY
MECHANICVILLE
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SPRINGFIELD
MONTREAL
BUFFALO
WASHINGTON DC
HARRISBURG

Fig. 1

travelled west on the line, meeting the Erie forces at Tunnel, where Ramsey's approximately 400 men fought Fisk's force of approximately 250 men. The battle continued until it was broken up by the 44th New York Militia. In 1870, the courts finally ruled in favor of Ramsey and the A&S; Ramsey immediately leased the road in perpetuity to the Delaware & Hudson Canal Company.

The original construction of the tunnel was performed employing drilling and blasting techniques. The end sections of the tunnel (323 feet from the west portal and 100 feet from the east portal) were lined with stone for the walls and brick for the arch; the remainder of the tunnel, 1,817 feet, was supported by timber and unlined. The timber was expected to be sufficient for a period not to exceed four years, and was replaced with a stone (for the walls) and brick (for the arch) lining within a few years of the tunnel being placed in service.

The tunnel as originally designed and constructed was equipped with wooden doors (which were removed in 1926, replaced in 1944 and removed again somewhat later) and without a vent shaft. The track grade rises from both sides of the tunnel and the point of intersection of the vertical curve (PVI) is at station 845+00, which is located 1,121 feet and 1,120 feet from the east and west portals, respectively. Railroad traffic employed pus er locomotives to make the grades with the result that substantial smoke was generated in the tunnel; it is reported that passengers would become groggy and that work forces could not work efficiently within the tunnel. With the advent of Class E3A locomotives, the gas problem became intolerable and a vent shaft was constructed in 1908. The location of the vent shaft and the schematic design is presented in Figure 2.

In 1941 the D&H commenced using Class E6A locomotives and gas generation once again became a problem. The gas problem was solved by lowering the grade by underpinning the stone walls and constructing a concrete bench. The concrete was unreinforced except for some used rail. This work was performed under service during the period from November 1941 to July 1943.

The tunnel was a continuous maintenance problem since its completion. The problems were primarily related to ice formation and accumulation on the track and deterioration of the lining of the tunnel. The deterioration of the lining required numerous repairs including replacement of segments of the lining with metal liners, repair and pointing of the brick arch, applying gunite to the brick arch and stone walls and the installation of rock-bolts in the crown. The bottom of the vent shaft was also closed to prevent the accumulation of ice at the bottom of the vent shaft, which could damage the passing trains and on the tracks, which could derail the traffic.

DESIGN INVESTIGATIONS

The design investigation of the tunnel was divided into three phases; an existing conditions survey, a preliminary subsurface investigation and final subsurface investigation. The existing conditions survey was comprised of an inspection of the interior of the tunnel and probing behind the lining where the lining was not intact. The preliminary subsurface investigation was comprised of test borings and a seismic survey; this work was performed by NYDOT. The final subsurface investigation and the design of the tunnel rehabilitation was comprised of test borings,

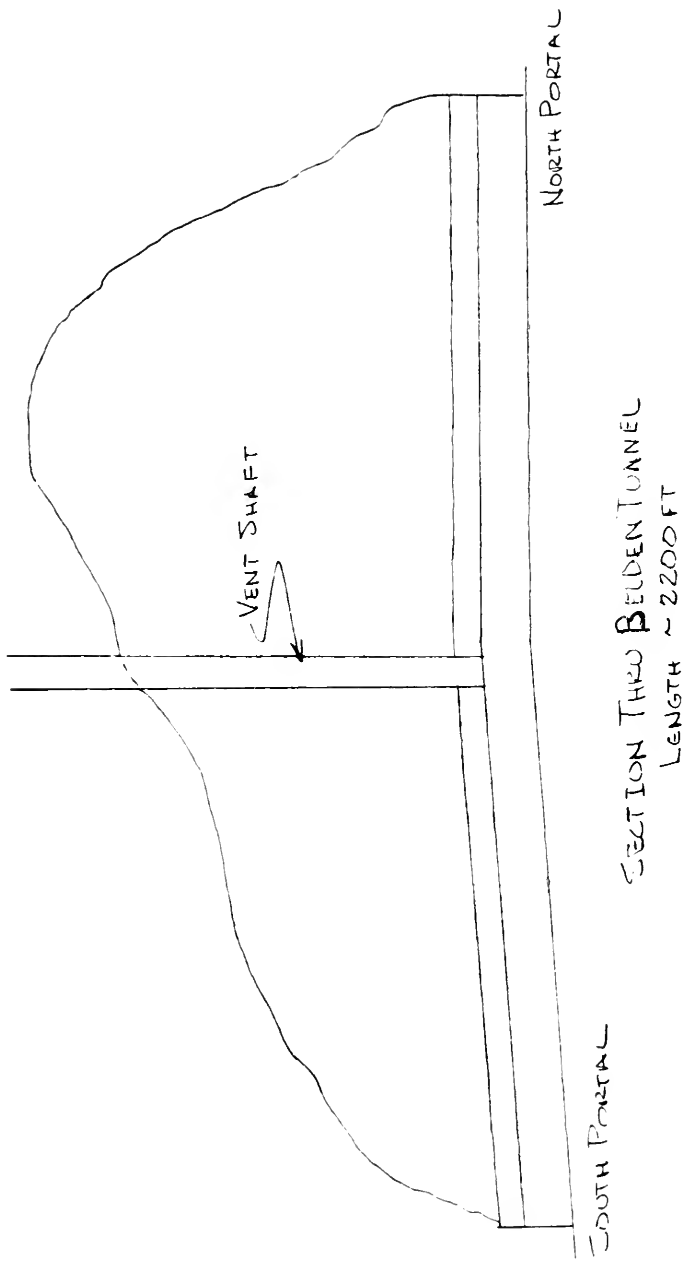
NORTH PORTAL
VENT SHAFT
SOUTH PORTAL
SECTION THRU BELDEN TUNNEL
LENGTH ~ 2200 FT

Fig. 2

probes of the lining and rock and fill behind the lining, installation of rockbolts and laboratory testing of the rock cores and ground water; this work was performed by FES, Inc. of Boston, Massachusetts.

Existing Conditions Survey

The existing conditions survey was performed in September 1982, and the results of this survey were presented to NYDOT in a report dated December 1982. The tunnel was visually inspected and observations were recorded for each consecutive 25 foot tunnel segment starting at the westerly portal and photographs of the conditions found were taken.

The primary conclusion drawn from the existing conditions survey was that the tunnel lining was not performing its function of supporting and protecting the surrounding rock so as to assure the stability and integrity of the opening.

Preliminary Subsurface Investigation

The preliminary subsurface investigation was performed by NYDOT between 17 August and 21 December 1982. This investigation was comprised of a seismic survey by the NYDOT geotechnical staff and four core borings adjacent to the existing tunnel alignment and five core boring along two alternative tunnel alignments. NYDOT personnel also performed permeability testing in selected borings during this invessigation. A total of 103 water pressure tests were performed in four borings, two of which were located along the alignment of the existing tunnel alignment and two of which were located elsewhere.

Final Subsurface Investigation

The subsurface investigation by FES was comprised of two borings which were taken from without the tunnel and located along the existing tunnel alignment, and twenty-five borings which were taken from within the tunnel at various orientations from the horizontal plane. The test boring rigs employed by FES were Joy, skid mounted, rotary drilling rigs, which have been especially modified for performing subsurface investigations within spaces such as tunnels with limited headroom conditions and are capable of drilling in any orientation. The drill rigs were mounted on an inspection car which was supplied by the D&H.

The rock coring operations were carried out under rail traffic. When notified that traffic was scheduled, the inspection car, together with a water wagon (1,000 gallon capacity), was moved outside the west portal onto a siding by a high-rail vehicle, and returned to the site of the drilling after the train had passed. This method of interrupting drilling operations naturally resulted in some inefficiencies; however, the cost of holding up the rail traffic or, in the alternative, diverting to an alternate route, was considered to be prohibitively expensive. Consequently, the exploration equipment was setup to be highly mobile and, despite frequent interruptions, the exploration was finished on time and on budget.

The coring operations revealed that the interface between the lining and the rock was comprised of broken rock, sand and gravel backfill, brick chips and miscellaneous debris. the material could not be cored because of the loss of drilling fluid exper-

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ienced and the tendency of the debris to jam the core barrel. The penetration of the tunnel lining was performed by using pneumatic equipment to remove the lining and expose what was judged to be rock which could be cored. The coring operations would then proceed using double-tube core barrels in NX size. The core recovered was removed from the core barrels and immediately placed in core boxes and logged by an FES geologist. A full description of the core was entered into the logs and the percent recovery and the Rock Quality Designation (RQD) were determined.

The thickness of the lining in the crown was too thick and unstable to allow removal so as to facilitate the rock coring; therefore, the thickness of the lining and the debris over the crown of the lining was determined by drilling through the lining and debris and into rock using pneumatic tools. This information was also employed to determine the rate at which the rock could be drilled. The drilling was performed using a Gardner-Denver, Model S83F, with a TFL14 telescopic feed, and a Timken button bit with AW rod. The data gathered from this exploration included the rate of penetration into the rock and the thickness of the lining and debris.

Subsequent to the drilling of the penetration tests in the crown, rockbolts were installed at selected locations employing one-stage epoxy. The rockbolts were Dywidag, 1 inch diameter and were installed using both Celtite and Fasloc T epoxy resin. The rockbolts were tested to failure after allowing the epoxy to cure.

Finally, water specimens were gathered for testing to determine the presence of any chemical(s) known to interfere with the setting up of the concrete, shotcrete and/or epoxy.

DESIGN OF REHABILITATION

The design of the tunnel rehabilitation was comprised of numerous separate, but often related, tasks. These tasks were: 1) tunnel lining; 2) portal structures; 3) vent shaft; 4) portal door; 5) drainage; 6) instrumentation; 7) track alignment and grade; 8) signal and lighting; and, 9) exterior drainage.

The tunnel lining design is a function of rock conditions at a particular location in the tunnel. Relevant rock conditions are those which will be encountered when the rock is removed to the limits of the proposed opening. The proposed minimum opening is specified by the AREA as shown in Figure 3, which also presents the present minimum cross section measured using a clearance car. The rock encountered within the zone of influence of the tunnel is comprised of fine, sandy shales, layers of thin-bedded sandstones and some thin beds of limestone and siltstone. The bedding plane is very nearly horizontal.

The RQD determined for the rock within the zone of influence of the tunnel is classified as good to excellent under the classification system proposed by Deere, et al. The support requirements for rock of this character are a function of the joint geometry and a pattern employing 5 to 6 foot centers is recommended. An important consideration influencing the final design was the type of rock existing in the tunnel and the fact that the project was a rehabilitation rather than a fresh cut into the rock. The rock type was a consideration in that the rock quality should be somewhat better than indicated in the borings since the RQD method of determining rock quality is not as accurate in

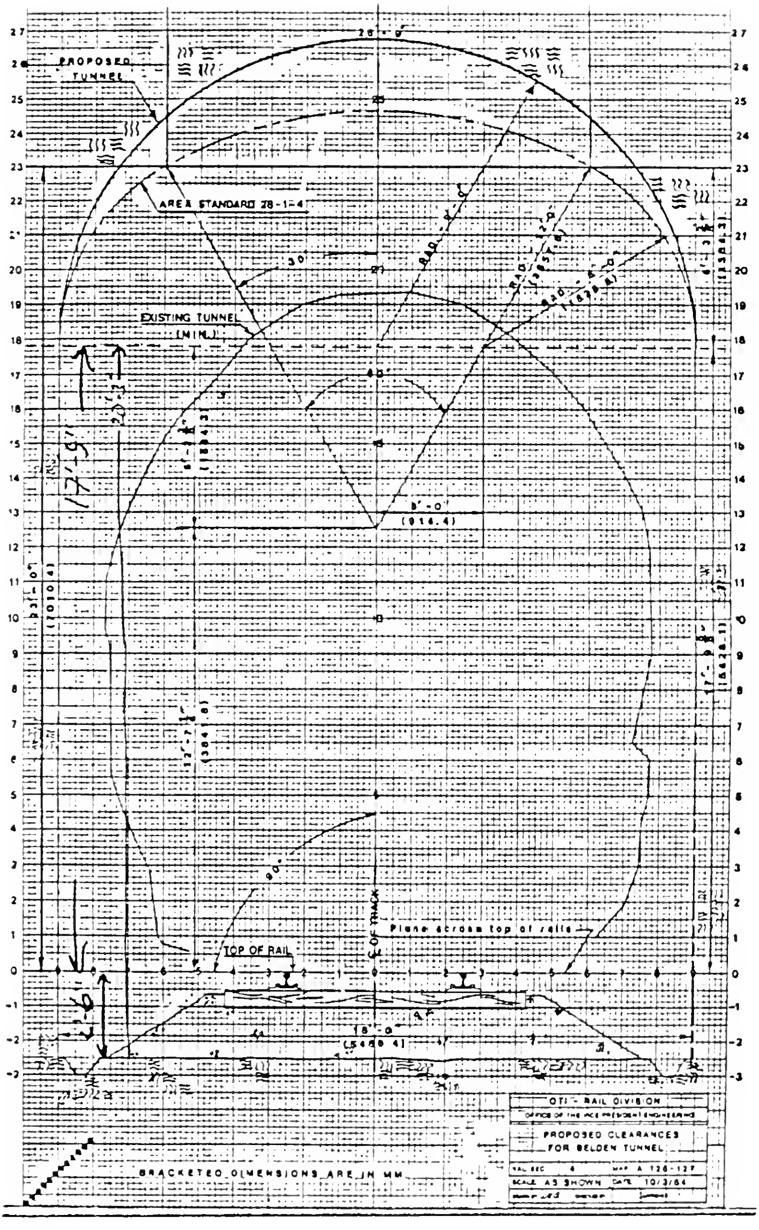
PROPOSED TUNNEL
AREA STANDARD 28-1-4
EXISTING TUNNEL (MIN.)
TOP OF RAIL
Plane across top of rails
℄ OF TRACK
BRACKETED DIMENSIONS ARE IN MM
OTI - RAIL DIVISION
PROPOSED CLEARANCES FOR BELDEN TUNNEL
SCALE AS SHOWN

Fig. 3

1920
Model 10

1929
Model 15

1950
Model 40

1982
Model 50

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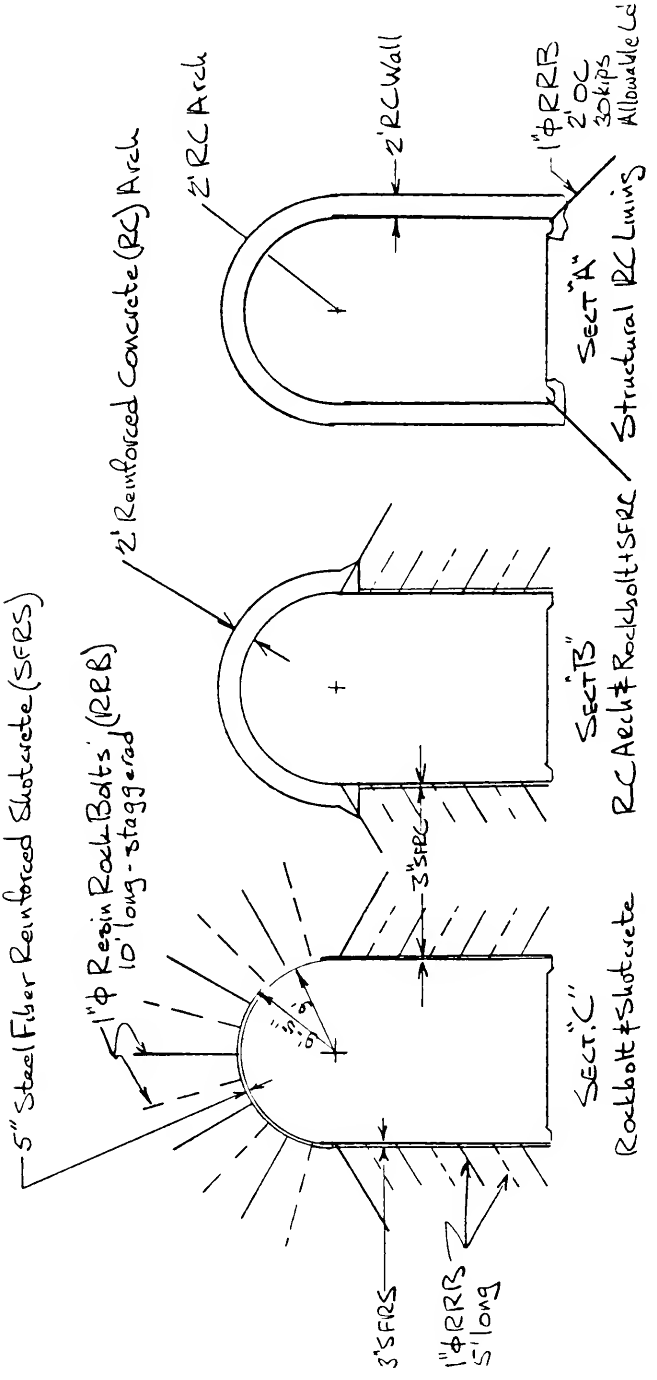
sedimentary and foliated metamorphic rocks as in igneous rocks, thick bedded limestones and thick bedded sandstones. This weakness was at least partially compensated for by careful examination of the breaks in the recovered core and evaluation as to whether the breaks were naturally occurring or the result of the coring and handling operations.

Thus, favorable RQD results actually underestimated the quality of the rock within the zone of influence of the tunnel. The design adopted in the design documents, 10 foot rockbolts on a pattern of 5 feet by 5 feet with fiber-reinforced shotcrete 5 inches thick, was therefore on the conservative side. However, the project is a rehabilitation job; that is, the tunnel was mined approximately 125 years ago, a brick lining was installed and over the intervening years, the lining has deflected, failed and been repaired to the net effect that the condition of the rock immediately surrounding the tunnel was in question, resulting in the design presented tending toward the non-conservative side. Based on the examination of the rock, inspections of the tunnel and the success of that portion of the tunnel overlying the concrete section at the north end which had been stabilized with rockbolts, all parties agreed that the rockbolt and shotcrete design was a practical, safe and cost effective design.

The design presented in the Contract Documents anticipated that portions of the tunnel near the portals of the tunnels would be in earth or mixed-face at the west end (south portal) and in shallow rock at the east end (north portal) and, therefore, that the tunnel support would be comprised of full reinforced concrete structural sections. At the east end, the thickness of rock overburden increased very quickly while, at the west end, sound rock was expected to be encountered at the elevation of the proposed spring line at a distance of approximately 100 feet in from the south portal. The design therefore included sections at both ends of the tunnel where the the reinforced concrete walls were eliminated and the crown was supported by a reinforced concrete arch. The side walls were designed to be reinforced with rockbolts to prevent lateral movement of the rock and subsequent loss of support capacity; the rock walls were to act as continuous columns supporting the reinforced concrete arches and the roof load.

Where the rock cover was sufficient, the design employed rockbolts and fiber reinforced shotcrete. The contractor was given the option of providing either steel fiber reinforcing or welded wire mesh. A minimum length and pattern of rockbolts for permanent support were specified as well as a minimum thickness of shotcrete and reinforcing for the shotcrete; the responsibility for the design and installation of all temporary support was placed on the contractor with minimum temporary support specified in the full structural sections. The selection of the shotcrete, as to the use of wet mix or dry mix, was left to the contractor. The contractor was also given the option of selecting the time of installation of the initial application and the final application of the shotcrete. The controlling factor in these design decisions was the necessity of completing the project within the time window of five months; the contractor was given all possible latitude in selecting his construction methods and procedures. The three design sections (full structural, structural arch and shotcrete and rockbolts) are presented in Figure 4.

The rehabilitation incorporated the original stone sidewalls of the south portal into the design; these sidewalls were in satisfactory condition and required only minor repair.



Design Sections

Fig. 4

The existing vent shaft had been closed at some time during the recent past. GTI decided to include opening and rehabilitating the vent shaft in the work under this contract. This decision was based partly on the necessity of the vent shaft to allow work in the tunnel under traffic conditions and partly on the cost to seal off the vent shaft if it were to be abandoned. Preliminary inspection of the shaft revealed that the condition of the vent shaft walls was questionable and probably would require repair whether or not the shaft was abandoned.

The decision to repair and retain the vent shaft was made by GTI and the NYDOT, and FES was directed to design a repair based on assumptions concerning the existing condition of the vent shaft and conduct inspections of the shaft during the rehabilitation. Based on the results of the inspections, the design of the rehabilitation would be modified as required. GTI designed a structure for the top of the vent shaft which allows the vent to be open or closed and thus controls the flow of air through the vent shaft.

GTI has had substantial success with a portal door installed at the Hoosic Tunnel, North Adams, Massachusetts. The portal door has reduced the number of trespass incidents in the tunnel, the amount of vandalism and, most importantly, the amount of ice damage within the tunnel. The wind rosette developed for the Tunnel, New York, area demonstrates prevailing winds are out of the west and aligned almost perfectly with the tunnel alignment.

As the result of the favorable performance at the Hoosic site, and the exposure of the tunnel to the weather at this site, GTI and NYDOT elected to install a portal door at the south portal of the tunnel. The history of the tunnel also suggests that the installation of a door at the tunnel is appropriate. The tunnel was originally constructed with doors that were later removed; installed once more and once again removed. The installation of doors during this rehabilitation will be for the third time; obviously, when the doors became a maintenance nuisance, the D&H decided to eliminate them and later, as ice and weather problems became intensified because of the greater exposure to the elements, the doors were replaced.

The door installed during this rehabilitation is operated electrically by the dispatcher in Binghamton and thus does not present some of the operational problems presented by manual doors. Further, the door is a vertical lift door provided with an enclosure to protect it when raised and is recessed from the portal to provide maximum protection to the door and its operating mechanism from the elements.

The drainage in the tunnel has presented substantial problems in the past and continues to be a source of concern. The tunnel necessarily acts as a drain for the mountain; to construct a tunnel that acted otherwise would require designing the tunnel lining for hydrostatic pressures and would greatly increase the cost of the rehabilitation. The objective is to provide a means of allowing the tunnel to drain and yet prevent the draining water from freezing either on the walls of the tunnel or on the floor of the tunnel.

This drainage problem is one which has been and continues to be a common problem of tunnels and open cuts in areas where freezing and thawing conditions occur. Numerous solutions have been tried; no method has proved totally successful. We have joined the ranks of those attempting new solutions.

In the contract documents, we have included drains in the structural and the shotcrete and rockbolt sections. These drains are merely open drill holes, drilled back into the rock for a minimum distance of 10 feet. During the construction of the tunnel, those areas which made water were observed and the drains drilled only at those locations. When the contractor finished his work, the D&H, using its forces, installed PVC drains with insulation at those drain locations which developed a sufficient quantity of water to provide a relatively constant flow and, therefore, enough heat to prevent freezing within the drains. The drain lines were fastened to the tunnel walls and carried down into the drainage ditch, which was provided with a corrugated metal pipe and sufficient cover to prevent freezing. The drain design is presented in Figure 5.

The instrumentation for the tunnel was designed to measure the extent of the rock adjustment to the excavation required to achieve the wider width and increased height, and to provide long term measurements of the movement of the tunnel lining so as to evaluate the performance of the tunnel and anticipate rock movements. The former purpose was satisfied by the installation of borehole extensometers, and the latter purpose was satisfied by the installation of tape extensometers.

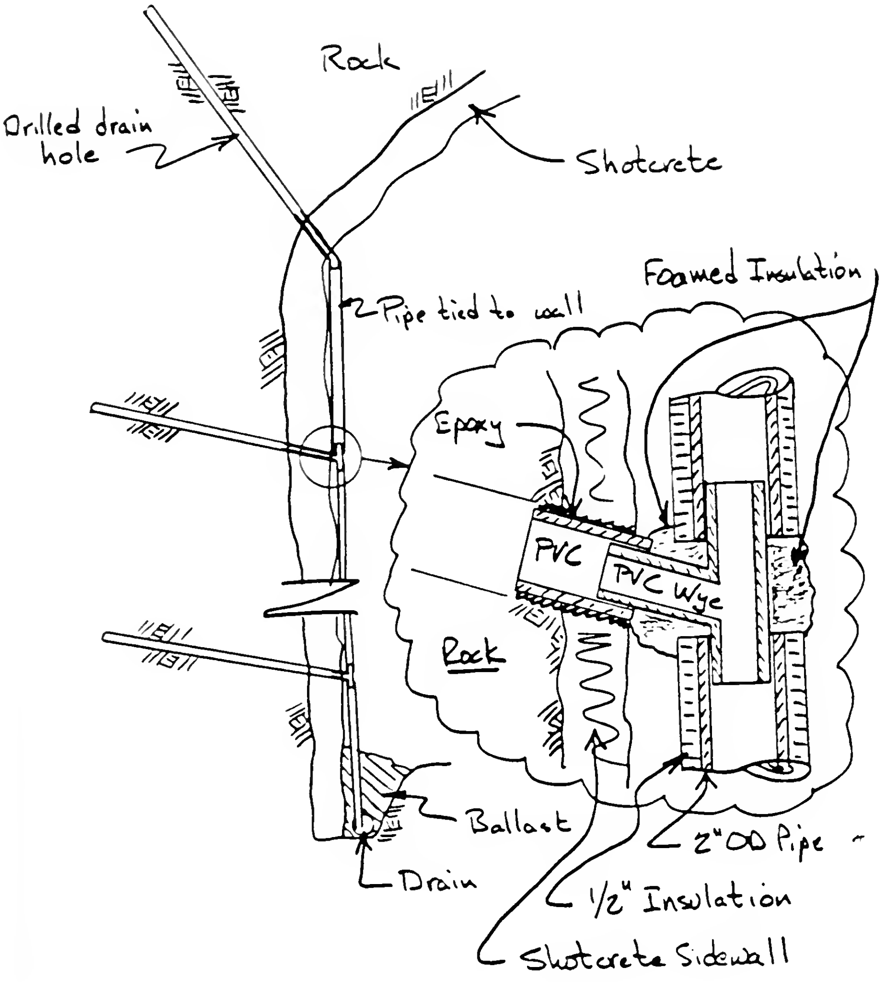
The track alignment and grade were improved. The grade was reduced the maximum possible without resorting to lowering of the tunnel invert, and the alignment at the north portal was changed from the existing circular curve to a log spiral curve. The signal and lighting were rehabilitated and all wiring was enclosed in conduit located within the tunnel. The exterior drainage was improved to facilitate the removal of the water from within the tunnel.

CONSTRUCTION

Project management was by FES, Inc., with Michael W. C. Emerson, Ph.D., P.E., principal in charge, Kurt Hackel, resident engineer, and a staff of six engineers and inspectors. The site office was equipped with an IBM, XT, which communicated, via telephone, with identical IBM equipment in the FES home office in Boston, GTI's home office in Boston, NYDOT in Albany and NYDOT, Region 9, in Binghamton. Vinay Mudholkar, Chief Engineer, directed operations for GTI; Mudholkar was assisted by John J. Parola, Chief Engineer, D&H. The Project Manager for GTI was Domenic T. Bua. The personnel with NYDOT in Albany, New York, who were instrumental in the engineering and administration of the project were Louis Rossi, Director, Rail Division; Benjamin S. Zodikoff, P.E., Director, Rail Operations; Michael J. Sheehan, Jr., P.E., Director, Project Engineering Section; Dan H. McAlonie, Project Manager; Henry Fastert, Project Engineer. Dennis Wilson was Construction Engineer in Charge of inspection for NYDOT, Region 9.

The construction was headed up for the Contractor, The Conduit and Foundation Corp., by Joseph F. Fox, Vice President, the Project Manager was Dan Goodwin and the Project Engineer was William Green.

The Contract Documents were prepared with the work divided into ten items and four alternates; viz., 100.01 North Portal Structural Section; 100.02 North Concrete Arch Section; 100.03 Central Section; 100.04 South Concrete Arch Section; 100.05 South Full Structural Section; 100.06 South Portal; 100.07 Repairs to



Tunnel Drain Fig. 5

Central Shaft; 100.08 Unclassified Excavation; 100.09 Rock Excavation; 100.10 Instrumentation Installation Allowance; and alternates, 200.01 South Portal Door, 300.01 Shotcrete South Sidewall, 400.01 Shotcrete Central Sidewalls and 500.01 Shotcrete North Sidewalls. Unit prices were required to be included in a subsequent section.

The Contract Documents anticipated that extras would arise since historically, predictions of rock and earth quantities in tunnel work have given rise to numerous disputes. Therefore, the Contract rock estimate of 3,000 cubic yards (CY) and the unclassified estimate of 15,000 CY were established for the purpose of comparing the bids and provisions were incorporated in the contract to request revised unit prices from the Contractor if and when the quantities overran or under-ran by in excess of 20%; at the Engineer's discretion, he could direct the work to be performed on a time and material basis (at 10 and 10) or employ the bid unit prices.

The remainder of the bid items were all-inclusive; that is, the price bid included all work incidental to the work of that item. The sole exception was the instrumentation which was to be carried by the Contractor as an allowance and expended only upon direction by the Engineer.

One of the critical factors of the project was the length of time required for the performance of the work. The diversion cost for the railroad exceeded $10,000 per day not including many factors which did not lend themselves to direct calculation such as the intangible cost to use the track of another system, the increased time of transit and the effect on customers, etc. Because of the critical nature of the time, liquidated damages in the amount of $12,500 per day were established in the Contract, and the Contract period was established as 150 calendar days. Thus, with significant liquidated damages, a very tight construction timetable and the limited construction season because of the impending winter months (the work was scheduled to be completed on 9 December), the Contractor needed to have as much latitude as possible in determining his construction methods and equipment.

The successful low bidder was the Conduit and Foundation Corporation, Elmwood Park, New Jersey, with a base bid of $4,752,132.00. All four of the alternates were directed to be constructed. Construction commenced on 8 July 1985 and was substantially completed on 23 December 1985. Contract time extensions, amounting to approximately one calendar week, resulting from changes in the work were granted the Contractor during the contract period.

The Contractor was encouraged to provide value engineering proposals and to propose innovative construction methods to facilitate an early completion of the work. C&F proposed to perform the tunnelling work at the south portal using open cut techniques to station 835+18 where the first sound rock was anticipated to be encountered and the work could turn under the rock crown and tunnelling in a total rock face could commence. A photograph showing the open cut work is presented in Figure 6.

During the work on the open cut, the rock excavation was commenced at the north portal (the date of the first tunnelling work on the north portal was 5 August 1985). C&F had determined that it would mine the tunnel in two passes; the first pass would

South Portal Crown Being Cast in Open Cut **Fig. 6**

perform the required mining of the arch, the installation of any necessary temporary support and the installation of the permanent rockbolts and the first lift of shotcrete, and the second pass would be employed to excavate the side walls, from approximately the springline down, and install the rockbolts. Any0portion of the tunnel which required either full or partial structural sections would be mined in a similar fashion depending upon the required temporary support.

The rockbolts were designed to be installed employing a preload; however, after approximately 40% of the arch rockbolts had been installed, the preload was eliminated because the stressing was resulting in surface punching of the rock and minor slabbing of the rock. The elimination of the preload reduced this problem.

The rock excavation was commenced using a road header, which is shown in the photograph presented in Figure 7. The road header is also shown during mining operations in the tunnel in Figure 8; this photograph also shows the heading which was typically comprised of the old brick lining, unclassified material behind the lining and sound rock. The road hea er made satisfactory progress except that during the excavation of the reinforced concrete in the arch at the north end, the reinforcing rods wrapped around the cutter on the header and damaged it, requiring the removal of the header from the tunnel for repair. The excavation was continued using drilling and blasting techniques. A three-drill jumbo was employed for the drilling, and a picture of the jumbo is presented in Figure 9. The blasting employed very light charges comprised of Tovex and Splitex. The Powder Factor varied between 0.8 and 1.6 pounds per cubic yard of rock. Drilling and blasting was employed in the north end until 7 September, when C&F considered that the drilling and blasting was causing surficial rock falls behind the heading in areas which had not received the first lift of shotcrete and which could be avoided if the road header were used rather than drilling and blasting.

C&F had started its shotcreting subcontractor, J. A. Blanck Company, Lanham, Maryland, placing the first lift on the arch at the north portal on 11 September, some 37 days subsequent to the commencement of mining; at that time, mining of the arch had progressed approximately 620 feet into the tunnel from the north portal. C&F continued mining with the header until the arch was shotcreted with the first lift, and on 15 September, C&F directed Blanck to place shotcrete at the face immediately following the installation of the rockbolts. After this construction technique was adopted, no further problems with rock falls were experienced.

The shotcrete employed carbon steel fibers as reinforcing. Design mixes were submitted for both dry-mix and wet-mix shotcrete, both of which employed 100 lbs per cubic yard of steel fibers. The wet mix designs employed plasticizers, water reducers and accelerators; the dry mix designs employed only accelerators. A photograph showing the shotcrete being placed is presented in Figure 10, and a photograph of the finished surface of the shotcrete is presented in Figure 11. The rebound was estimated to be as high as 40% for the dry-mix and between 10 and 30% for the wet-mix.

Shotcrete quality control was provided through the use of test panels which were formed when and as directed by the inspec-

Fig. 7

Road Header Mounted on Backhoe

Fig. 8

Road Header at Tunnel Heading

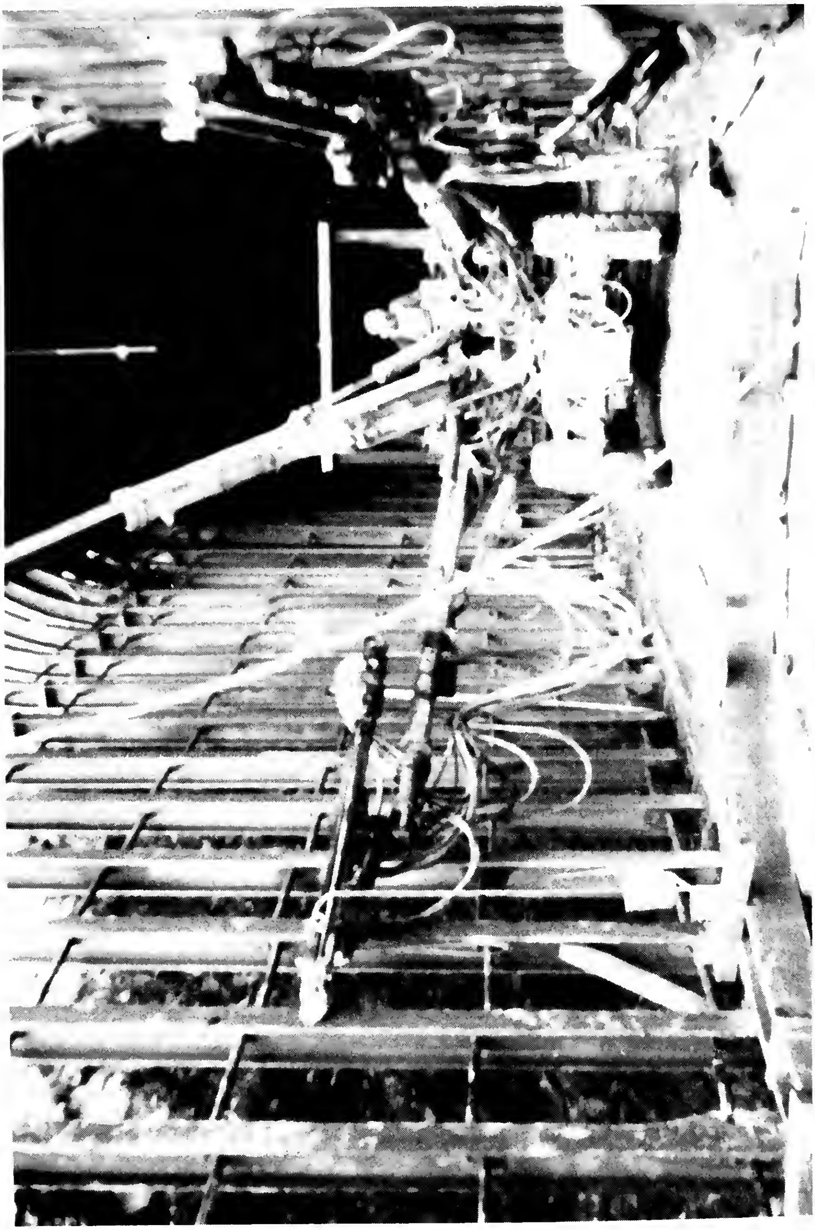


Fig. 9

Three Drill Jumbo

Fig. 10

Fiber Reinforced Shotcrete Being Placed

Fig. 11

Shotcrete in Place on Arch

tors. The test panels were cored to produce cylinders for unconfined compression testing and were sawed to produce beams for flexural testing. The steel fibers were added to the shotcrete at the site and the quantity was verified by the inspectors. The uniformity of the in place shotcrete was determined by taking cores and breaking these longitudinally for visual examination. The depth of shotcrete in place was monitored by drilling holes through the shotcrete and measuring the thickness of the shotcrete.

C&F commenced mining in the north end of the tunnel employing drilling and blasting techniques on 24 September and, with the exception of a few isolated days, completed the mining of the arch to the vent shaft employing drilling and blasting. The mining of the arch on the north side was completed to within 5 feet of the vent shaft on 26 October 1985; work was stopped short of the vent shaft to allow the inspection of the vent shaft to be completed and the vent shaft repairs to be designed.

Mining of the arch on the south side where the open cut was terminated commenced on 19 August; the road header was employed. At the south end, C&F attempted to use the A Section steel sets for the arch; however, the feet for the sets could not be founded on sound rock because of the technique which had been employed to mine the tunnel during the original construction.

Subsequent to the mining of the original arch, the tunnel was deepened by drilling vertically downward from the arch and blasting. This construction technique resulted in the width of the tunnel required to be excavated to reach sound rock being greater than the width of the steel sets which were designed for the B Section. A field change was instituted which eliminated the B Section (reinforced concrete arch) and replaced this section with a modified A Section. This modified A Section was employed in lieu of the B Section at both ends of the tunnel and was carried to Stations 835+80 and 855+60 and the south and north ends of the tunnel, respectively.

Tunnelling required for the Modified A Section was completed on 5 September, and mining for the south end arch, where the modified C Section terminated, was commenced on 6 September using the road header. On 28 September, C&F commenced using drilling and blasting and continued until 5 October (Sta. 839+90) when they returned to the use of the header. The header was employed through 17 October, at which time the use of drilling and blasting was interspersed with the use of the header until the arch was complete to within approximately 5 feet of the vent shaft (Sta. 844+90, 13 November) and the operation halted to allow inspection and design of the vent shaft repairs.

Subsequent to the completion of the arch, C&F proceeded with the excavation of the sidewalls of the tunnel, performing the excavation using a Hoe-Ram mounted on a backhoe as shown in the photograph presented in Figures 12 & 13. The rockbolting was performed concurrently with the excavation of the sidewalls, and both operations were completed on 13 December. The excavated materials were removed from the tunnel floor by C&F subsequent to cutting drainage ditches on both sides of the tunnel floor. On 26 December 1985, the Contractor turned the tunnel over to the D&H Railroad forces to allow the installation of approximately 4,000 ft of track. The track work was performed by the railroad forces working around the clock, and the track and tunnel were put in revenue service on 28 December 1985.

Hoe Ram Removing Concrete Bench **Fig. 12**

Fig. 13

Hoe Ram Removing Rock in Sidewall

The vent shaft inspection and redesign was completed on 8 November. C&F proceeded with the work on the vent shaft on 16 December and completed the scaling and rock bolting on 19 December. At that time, the work remaining consisted of the installation of the drains, sidewall shotcrete (approximately 30%), and the placement of the shotcrete for the vent shaft repair. Because the cold weather had commenced for the season with no relief anticipated, and since the work had been substantially completed, GTI and C&F agreed that the remaining work, including the portal door, the remainder of the wall shotcrete work, application of shotcrete at a few isolated locations on the arch and the installation of the drains would be deferred until the spring of 1986, and this remaining work would be performed under traffic. We anticipate completion of the work in May 1986.

Throughout the project, the element most essential to the successful completion of any complex project was always present; the willingness and ability of all parties to work toward the resolution of all problems encountered so as to facilitate the completion of the project on budget and on time.

The Real Crisis in Engineering Education

A. D. Kerr*

For the past several years many publications appeared that declare and then discuss the "crisis in engineering education". This crisis is being confirmed, from time to time, by reports of special committees and panels that were appointed by a variety of organizations and institutions. According to these publications, the two main elements of the crisis are: (1) a shortage of engineering faculty and (2) outdated laboratories in our engineering schools. The proposed remedy is generally the same: Allocation of more government funds to universities.

The purpose of the following remarks is to show that although a crisis in engineering education indeed exists, its nature is very different than perceived by the various panel and committee reports. It is the opinion of this writer that the real crisis is related to the engineering curricula, namely the lack of balance between engineering design and engineering science, and the adverse effect this situation has on U.S. industry and economy. The remedy for these problems does not depend on government funds, but rather on decisions by university administrators, and various faculty committees. However, this solution may not be popular in, and much more difficult to face by, academia since it requires actions within the universities, without immediate financial rewards. The often quoted shortage of engineering faculty members is attributed here mainly to the distortion of the present curricula and the related appointment practices of engineering professors. To provide a focus, the following remarks will be restricted to mechanical and civil engineering.

Engineering education in the USA, which started during the nineteenth century, was originally of a very practical nature. However, this drastically changed after World War II, especially during the aerospace period in the late 1950's and early 1960's. NASA, faced with formidable problems associated with space flight and the planned landing on the moon, and backed up by extensive federal funds, started a broad program of funding university research. After World War II other sources of research support were also created by the armed forces through the Air Force's OSR, the Navy's ONR, the Army's ARO, and through grants and contracts allocated by other federal agencies and research laboratories. This funding was in addition to the research grants of the National Science Foundation.

Because of the availability of these funds, university administrators (presidents, deans, and department chairmen) adopted policies aimed at maximizing the research income for their schools and/or departments. In addition, they hoped that the resulting increase of research papers would make their institutions better known to those outside. An essential step toward this aim was to appoint young Ph.D.'s for new faculty positions, since they are trained to do research and their starting salaries are relatively low. This practice has been in effect for the past three decades. For example, when an engineering professor retires and a faculty opening is created, the standard procedure in the United States (with very few exceptions) is to fill it with a young assistant professor, regardless if the position is to cover design or the engineering sciences.

A typical successful applicant for a vacant assistant professorship is usually a Ph.D. student who has spent four or five years in graduate school, has completed a doctoral thesis, and has decided to start his academic career immediately upon graduation. However, at present a bachelor degree program in engineering has very few design courses, and the Master's and Ph.D. programs in engineering departments cover mainly engineering science and mathematics. Therefore, a young Ph.D. has, upon graduation, generally no experience in engineering design and/or practice.

At the university, some young faculty members are faced with the task of teaching one of the few design courses that have been retained in the curriculum. Often, that person is given a textbook (or is asked to find one) and is told to prepare for teaching a design course the next semester. Not having experience in design, the young assistant professor adheres to the text. After teaching this course for several years, he is considered as the professor in charge of this particular design course (thus an "expert" designer), although he/she never designed an actual structure or mechanical device.

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*Professor, Department of Civil Engineering, University of Delaware

During the initial five years on the faculty, the young professor is involved in writing and publishing papers and getting research grants. These activities are key elements in tenure considerations. Here, the emphasis is generally on the engineering sciences, in which it is easier to publish papers and receive grants. The design course is taught as a necessity. Instead of working during the summer in an engineering office to gain design experience, the young faculty member spends that time instead at the university or a research laboratory writing engineering science papers. The result is that the assigned design course becomes a routine exercise taught by an inexperienced and often uninterested lecturer. The situation is getting worse as the "old timers" who have some design background retire and an increasing number of young Ph.D.'s are taking over their courses (provided these courses are not eliminated altogether).

The practice of appointing recent Ph.D.'s to professor positions with a responsibility of teaching design as well as analytical courses, has led to a major shift in the curricula toward the engineering sciences and a strong neglect of engineering design. Should this trend continue, soon the programs in the engineering departments at U.S. universities will be essentially engineering science programs and thus, at best, pre-engineering programs. The main factor that presently is delaying this development is the (minimal) accreditation requirements by ABET.

At this point, it is instructive to consider the corresponding situation in West Germany; a major competitor of our industry. There, for the first two years the engineering student is taught mainly the fundamentals, but during the next two to three years the emphasis is on design. The aim of these programs is that upon graduation, a degree holder should be able to design in his/her branch of engineering, which also includes the preparation of the necessary blueprints. This is generally not the case in the United States.

To cover these curricula, in Germany each "department" has an allocation of teaching positions for the various specialties. A new appointee for one of the many professorships in design, is generally chosen from among outstanding engineers with extensive design experience in industry, unlike in our country where often young inexperienced Ph.D.'s are given the task of teaching design. Many countries on the European continent, as well as Japan, follow essentially this pattern; thus, they produce well educated engineers, rather than engineering scientists.

It is therefore not surprising that many of these countries out-design, out-produce, and out-sell the United States when it relates to mechanical devices like cars, appliances, machine tools, electrical equipment, steel products, etc. This appears to be the reason why Japan and Germany are presently posing a threat also to our computer industry, which for years was a leading developer in this field.

It is conceivable that the current education of our engineers is contributing to the size of our defense budget, since the successful and economic development of new weapons depends strongly on the design expertise of the engineers involved. To be able to do it right the first time around, is an important factor in the cost of military hardware.

The federal government and industry are beginning to realize that something is not right with American engineering education. The recent announcement by the National Science Foundation that it is granting 94.5 million dollars for five years to a number of universities to form and operate six national research centers with the goal to develop fundamental knowledge "that will enhance American industry's international competitiveness and help engineering students prepare for professional practice" indicates a recognition of this problem. The funding of these centers is a step in the right direction. However, this is an attempt to fix the problem from above and therefore its achievements should be of limited scope. It appears to this writer that it is necessary to complement the centers by a "grass-root" approach; namely, an attitude change in our engineering schools toward design.

As described above, presently the academic programs and teaching emphasis in engineering colleges are badly distorted toward the engineering sciences. The first and most essential step in alleviating this situation is to establish in each department a sense of balance between the faculty positions in the engineering sciences and engineering design. It appears that in order to cover properly the undergraduate programs one design professor for every four in the engineering sciences is a bare minimum. In order to also offer graduate courses, the ratio of two to three appears more appropriate.

An incoming design professor should have proven himself in industry for at least 25 years as an outstanding designer in a branch of engineering. Additionally, that person should be enthusiastic about teaching design and be a good lecturer. The Ph.D. should not be required for positions of this type. Generally, tenure should be granted at the start of their full-time teaching activities, in order to attract these specialists to academia. The main responsibility of a design professor should be to teach inspiring design courses on the undergraduate and graduate levels, to supervise senior design projects (when necessary), and to work on novel designs that may not have been possible during their industrial careers.

The appointment of experienced engineers to design professorships will not only greatly improve the education of engineers, but it will also contribute to the solution of the well publicized problem of the "engineering faculty shortage." It is the opinion of this writer that this shortage is mainly due to the present lack of balance between the engineering science and (true) design appointments and is not solely due to the reduced production of Ph.D.'s, as is usually claimed.

The design requirements for accreditation of engineering programs by ABET will be more meaningful if there will be experienced designers on the faculties to teach the necessary courses. In this connection it should be noted that the introduction of computer aided design (CAD) courses is very important for the education of a future engineer. However, these courses should be considered a supplement, and not a substitute, for introductory and advanced courses by outstanding designers.

In conclusion, it is worthwhile to note that the move from engineering design toward the engineering sciences in our engineering schools has had parallel developments in industry and the military. For example, the recent suggestions that U.S. industry switch from a manufacturing to a service industry is one such development. It appears reasonable to suggest that the failure of our engineering schools to produce well educated engineers is also contributing to this situation. It is not sufficient to improve only productivity and quality control. Industry needs well designed products to effectively compete with foreign products abroad as well as at home. Another parallel development is in the military establishment, as evidenced by the increasing emphasis of management and related areas among the officer corps, as compared to combat related subjects and activities. All of these developments, if not reversed, may have serious consequences for our economy and national security.

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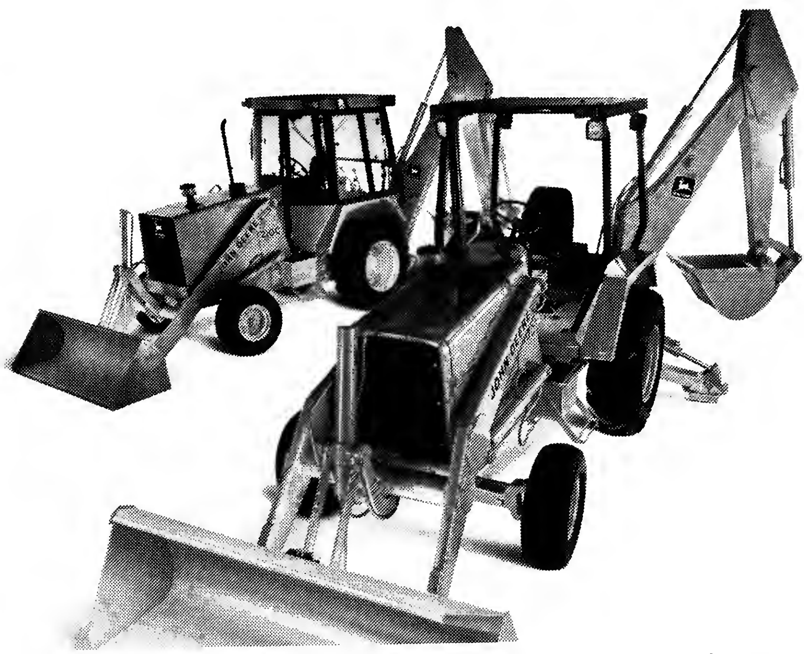

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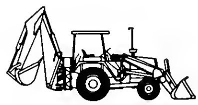

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710B BACKHOE LOADER
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JOHN DEERE

RIGHT FOR THE TIMES

PUBLISHED AS INFORMATION

COMMITTEE 14—YARDS AND TERMINALS

Report on Assignment No. 4

Facilities and Procedures for Handling Cars not to be Humped

J.R. Clark (Chairman, Subcommittee), M.J. Anderson, W.A. Schoelwer, J.S. Acs, B.H. Clarke, Jr., H.E. Buchanan, H.D. Crawley, F.D. Day, G.N. Dorshimer, D.A. Harrison, D.L. Hatcher, W.J. Hedley, P.E. Hubbard, T.B. Levine, M.L. Sevier, D.A. Shoff, M.C. Walbrun, J.C. Weiser.

Your committee submits this report as information with the recommendation that this subject be discontinued.

A. Introduction

This report is based on a survey of existing facilities and procedures used for handling cars which cannot be humped, hereafter called "No-Hump" cars, in a hump classification yard. The survey covered 35 hump classification yards located on 9 rail systems throughout the United States.

B. Definition

No-Hump cars may consist of, but not be limited to, any of the following:

1. Cars containing hazardous materials.
2. Cars placarded "Explosives A" or "Poison Gas".
3. Any car placarded "Do Not Hump".
4. Tank cars that have no bills.
5. Piggyback or TOFC/COFC.
6. Special equipment such as Deep Well or Schnable cars which may not be able to traverse retarders, or vertical curve at crest of hump.
7. Passenger cars equipped with disc brakes.
8. Any other equipment or lading which may be restricted by Carriers Special Instructions or Operating Rules.

C. Facilities for handling cars not to be humped.

In most older hump yards surveyed there are no facilities provided specifically for No-Hump cars, but in all yards there are special handling procedures. In some yards, particularly those built recently, specially designed No-Hump tracks have been provided. One or two in number these tracks are generally double ended and located as near to the crest of the hump as practicable with entry switch on hump lead. Grade, where possible, is level and alignment is tangent. Capacity varies from 2 to 16 cars depending on relative volume of No-Hump cars handled. No-Hump track may be equipped with inert retarders, skates, derails or other protective devices.

D. Procedures used for handling No-Hump cars

1. Where No-Hump track(s) provided:

a. No-Hump car is shoved to rest on No-Hump track by hump engine and handbrakes are set. Car is subsequently moved by yard engine to Departure Yard, placed directly in train, or shoved to rest in classification track, after other cars have been humped, and hand brakes are set or car is otherwise secured.

2. Where No-Hump track is not provided:

a. Car(s) and following car(s) are shoved to rest in classification track by hump engine.

b. Car is shoved to rest in classification track by hump engine and track is blocked to preclude humping another car into it. Subsequent cars destined to that track are given alternate assignments.

c. Car is humped into open class track and protected.

d. Car is set out in Receiving Yard and handled by special move. Hump is bypassed.

COMMITTEE 22—ECONOMICS OF RAILWAY CONSTRUCTION AND MAINTENANCE

Report of Subcommittee No. 6

Economics of Shop Welding 39 Foot vs. Long Rail Into CWR Strings

S.H. Morrell (Subcommittee Chairman), W.E. Glavin, R.S. Johnson, J.T. McBain, B.G. Sykes

In order to determine what factors influence the conversion of a plant to long rail capacity, our subcommittee sent out a questionaire to 16 Class I railroads and 14 responses were received.

The responses to the questions indicate certain trends:

1. If the railroad's annual requirements are over 500 miles, the requirements are met only if the existing plants(s) can handle long rail.

2. In making the decision to modify welding plants to handle long rail, plant production requirements at the present or future time are as critical as cost savings from making fewer welds.

3. Equipment for handling materials and long cars were more significant factors than track changes to accommodate long cars and increased freight charges.

4. Of the five plants that could not handle long rail, four were planning to build plants more to reduce welding costs than to meet future requirements.

5. The same number of personnel were employed regardless of rail length.

6. Floating inspection stations are critical if production levels are to be maintained. Despite floating stations, whatever lengths are being welded must be consistent or the cycle (and the production rate) become distorted.

In conclusion, production requirements are as critical, if not more critical than, reduced costs if the annual rail requirements are over 500 miles. If the annual requirements are being satisfied with 39 foot rail, cost is the deciding factor. There is little concern over future availability of 39 foot rail. Long rail produces twice the rail with little change in variable cost resulting in a very favorable payback.

The attached tables provide a summary of questionnaire responses.

FACILITY DATA

RAILROAD	MAINLINE TRACK MILES	MAINLINE CWR MILES	PRODUCTION PER MACHINE HOUR 39′	PRODUCTION PER MACHINE HOUR LONG	ANNUAL CWR REQUIREMENTS TRACK MILES	NO. OF WELDING MACHINES	ANNUAL REQUIREMENT SATISFIED
A	10,490	6,390	15	12	N/A	2	YES
B	11,490	7,520	14	—	550	2	MARGINAL
C	12,000	7,900	14	12	300	3	YES
D	20,910	11,500	13	12	800	2	YES
E	190	110	N/A	N/A	10	N/A	N/A
F	1,000	300	20	—	20	1	YES
G	15,600	7,400	14	—	600	3	NO
H	17,100	8,700	13	—	475	4	YES
I	7,700	2,300	17	15	210	2	YES
J	6,000	3,500	10	10	N/A	2	YES
K	6,800	2,900	18	—	100	1	YES
L	28,000	11,700	17	16	1,100	5	YES
M	22,000	8,100	13	10	N/A	9	YES

RAILROAD DATA

RAILROAD	MAINLINE TRACK MILES	MAINLINE CWR MILES	ANNUAL CWR REQUIREMENTS TRACK MILES	NUMBER OF WELDING FACILITIES				
				CO. OWNED/ OPERATED	CO. OWNED CONTRACTOR OPERATED	CONTRACTOR OWNED/ OPERATED	OTHER	NUMBER OF STATIONARY WELDING MACHINES
A	10,490	6,390	N/A	—	1	1	—	2
B	11,490	7,520	550	1	—	—	—	2
C	12,000	7,900	300	3	—	—	4 Mobile	3
D	20,910	11,500	800	—	1	—	—	2
E	190	110	10	—	—	—	Purchased	—
F	1,000	300	20	—	—	1	—	1
G	15,600	7,400	600	1*	—	—	—	3
H	17,100	8,700	475	—	1	1	—	4
I	7,700	2,300	210	—	—	—	1**	2
J	6,000	3,500	N/A	—	1	—	—	2
K	6,800	2,905	100	1	—	—	—	1
L	28,000	11,700	1,100	—	3	—	—	5
M	22,000	8,100	N/A	3	—	—	—	9

* — Equipment partly owned, partly leased, railroad operated
** — Company owned facility, contractor owned and operated equipment

FACTORS FOR MODIFICATION TO HANDLE LONG RAIL

ONLY RAILROADS WITH CAPABILITY TO HANDLE LONG RAIL

	RAILROAD AND ITS PRIORITIES (1 = Highest)							
SIGNIFICANT FACTORS	A	C	D	I	J	L	M	AVG
Reduce welding cost by use of long rail		1	1	1	2	2	4	1.8
Savings to be gained from making fewer welds	1	1	3	3	3	1	1	1.9
Increase plant production to meet anticipated future requirements		2	1		5	3		2.8
Increase plant production and reduce costs by operating plant for less hours per year	2	2			6	4	3	3.4
Increase plant production to meet normal requirements				4	1	6		3.6
Increase plant production and reduce costs by operating plant with less personnel				2	4	5		3.7
Realization that 39 foot rail may not be readily available in future, or only at premium price	4	4			7	7		5.5
Other	3[a]	3[b]		5[c]			2[d]	

a-Eliminate outside welding by contractors

b-Handle long rail released from curves

c-Higher quality due to less welds per mile

d-Eliminate leased plants

MEMOIRS

Seldon Amzi Cooper
1913-1983

Seldon (Sam) A. Cooper, retired Chief Engineer - Southern Lines of the Illinois Central Gulf Railroad, died on July 18, 1983 at Mobile, Alabama.

Sam was born on September 26, 1913 at Dixon, Mississippi. He was graduated from Mississippi State College with a B.S. Degree in Civil Engineering in 1935. He was married to Monta Glee Allman on September 11, 1940 at Lucedale, Mississippi.

In May of 1935 Mr. Cooper began his railroad career with the former Gulf, Mobile and Northern which later became the Gulf, Mobile and Ohio, as Assistant Engineer at Union, Mississippi; March of 1937 as Assistant Supervisor at Union and in 1938 at Laurel, Mississippi; November of 1938 as Assistant Engineer, System, back at Union; May of 1946 as Resident Engineer, System at Mobile, Alabama; May of 1957 as Chief Engineer and in August of 1972 until his retirement on April 25, 1975, with the Illinois Central Gulf as Chief Engineer - Southern Lines at Mobile.

Mr. Cooper became a member of the American Railway Engineering Association in 1952 and a Life Member in 1977 and served as a Director from 1968-1971. He was appointed to Committee 22, Economics of Railway Construction and Maintenance in 1958 and elected Member Emeritus in 1982. Sam belonged to the Roadmasters and Maintenance of Way Association and the American Railway Bridge & Building Association, joining both in 1957 and becoming a Life Member of both in 1975. He also was a member of the Chicago Maintenance of Way Club, State Chairman of AAR Grade Crossing Committee - State of Alabama and active member of Dauphin Way Methodist Church where he served as Steward 1970-1972.

Surviving Sam is his wife Monta Glee of Mobile, Alabama.

All of his many friends, Committee 22 members and his associates are saddened to hear of his passing and express their sympathy and sorrow.

C. P. Davis

Patrick Allan Cosgrove
1916-1984

Patrick A. Cosgrove, retired System Engineer-Training, of the Illinois Central Gulf Railroad, died April 25, 1984 at his farm in Carrier Mills, Illinois.

Pat was born on January 3, 1916 at L'Anse, Michigan. He was graduated from Michigan College of Mining and Technology, Houghton, Michigan with a B.S. degree in Civil Engineering in June of 1937. He was married to Violet Kidd on May 3, 1943 at Carbondale, Illinois.

Before coming to the former Illinois Central Railroad on May 1, 1840, Mr. Cosgrove worked as rodman, instrument man and Junior Engineer for the Ford Motor Company, Chicago, Milwaukee, St. Paul & Pacific Railroad; as consulting engineer and the P.W.A. of the federal government. Pat spent the balance of his working career with the Illinois Central and the Illinois Central Gulf Railroad. For all but two years between September 1962 and September 1964, when he was Assistant Engineer Maintenance of Way at Chicago, Pat spent on what is now known as the Midwest Division. His first position was chainman headquartered at Champaign, Illinois. He progressed to Assistant Road Supervisor, Acting Track Supervisor, Track Supervisor, Division Engineer and at the time of his retirement on May 28, 1982 he was System Engineer-Training.

Mr. Cosgrove became a member of the American Railway Engineering Association in 1944 and a Life Member in 1983. He was appointed to Committee 22, Economics of Railway Construction and Maintenance in 1946 and remained on it until his retirement. Pat was also active in the Roadmasters and Maintenance of Way Association, joining in September of 1962, becoming a Life Member in July of 1982 and serving as Director from 1978 to 1982.

Surviving Pat are his wife Violet, a daughter Patricia Ann Bromiel, both of Champaign, and four sons, Michael A. of Chesterfield, MO, Stephen E. of North Pole, Alaska, Thomas J. of Lincoln, IL and David H. of Nashville, TN, seven grandchildren, one brother, Robert of Glen Ellyn, IL and one sister, Elizabeth Deschaine of L'Anse, MI.

All of his associates, friends and Committee 22 members express their sympathy and sorrow on his death.

C. P. Davis

William Matthew Jaekle
1912-1986

Bill Jaekle, a long time member of AREA, a Life Member 1978, a member of several committees and past director (1958-1960) died in Oakland, California January 28, 1986 from a heart attack.

Born in Portland, Oregon in 1912 he married his wife Wanda in 1942. Also surviving are their two daughters Sandra Shelton and Sue McDermed and one grand son Abraham Shelton; brothers Robert M., George B. and Charles Bruce Jaekle.

Graduating from Stanford University with a degree in Civil Engineering he went to work for the Southern Pacific Railroad following in the footsteps of his father (W.M. Jaekle) who was Engineer of Maintenance of Way and Structures. Working up through the engineering department he was an inspector on the Shasta Dam line change, then Asst. Divn. Engr. at Ogden, Utah and Oakland, Calif. He was then appointed Division Engineer at El Paso, Texas and later at San Francisco. He then was moved to Oakridge, Oregon in charge of the Lookout Point line change. In 1951 he went to San Francisco as Asst. Engr. MofW&S, was then promoted to Asst. Chief Engineer and Chief Engineer. In 1960 he was named General Manager and after several years was appointed as Vice President Engineering and Research which position he filled until his retirement in 1977.

In addition to AREA he belonged to ASCE, the Roadmasters and B&B Associations. He was also a past member of Orinda Country Club and the Pacific Union Club in San Francisco.

He was most active in research and car design and had a host of friends and associates in the railroad industry. He will be missed by the many people whom he met in these years.

H. M. Williamson

Harold W. Kellogg
1905-1984

Harold W. Kellogg, a member and former chairman of AREA Committee 22, died in Richmond, Virginia on December 30, 1984.

Born in Atlanta, Georgia November 21, 1905, Kellogg graduated from the University of Michigan in 1928 with a degree in Civil Engineering. His railroad career began as a rodman for the old Pere Marquette Railroad-later Chesapeake and Ohio-in 1928. Harold served in many capacities in the

Engineering and Maintenance Departments in Michigan and was promoted to Assistant Chief Engineer of the Chesapeake and Ohio Ry. at Richmond, Va. in July 1956. He served in this position until the merger of the Chesapeake and Ohio and the Baltimore and Ohio and was Regional Assistant Chief Engineer of the Chessie System at Richmond, Va. when he retired on February 1, 1970.

Harold joined the AREA in 1944 and served on the Board of Directors from 1966 to 1968. He was also active in the Roadmaster's and Maintenance of Way Association and served one term as President of that organization.

J. W. Brent

O'NEILL & GASPARDO

CERTIFIED PUBLIC ACCOUNTANTS

837 EAST 162ND STREET • P.O. BOX 83
SOUTH HOLLAND, ILLINOIS 60473
333-4000

January 20, 1986

Accountant's Report

Board of Directors
AMERICAN RAILWAY ENGINEERING ASSOCIATION
50 F Street N.W.
Washington, D.C. 20001

We have examined the balance sheet of AMERICAN RAILWAY ENGINEERING ASSOCIATION as of December 31, 1985 and the related statement of income and expenses for the year then ended. Our examination was made in accordance with generally accepted auditing standards and accordingly included such tests of the accounting records and other auditing procedures as we considered necessary in the circumstances.

In our opinion, the accompanying balance sheet as of December 31, 1985 fairly presents the financial condition of AMERICAN RAILWAY ENGINEERING ASSOCIATION in conformity with generally accepted accounting principles applied on a consistent basis.

O'Neill & Gaspardo

O'NEILL & GASPARDO

American Railway Engineering Association
Balance Sheet
December 31, 1985

ASSETS

Current Assets		
Petty Cash	$ 100.00	
National Bank of Washington-Checking	42,522.67	
National Bank of Washington-Savings	16,403.71	
Community Savings & Loan - NOW Acct.	8,898.45	
Investments	280,186.80	
Accounts Receivable - Dues	14,853.75	
Inventory	45,782.00	
Accrued Interest Receivable	3,788.08	
Total Current Assets		$ 412,535.46
Fixed Assets		
Furniture & Fixtures	$ 11,879.46	
Less: Accumulated Depreciation	5,827.00	
		6,052.46
TOTAL ASSETS		$ 418,587.92

LIABILITIES AND MEMBERS' EQUITY

Current Liabilities		
Expenses Payable		$ 47,409.85

MEMBERS' EQUITY

Beginning Balance	$ 351,053.40	
Plus: Excess of Income over Expenses for Current Year	20,124.67	
Total Members' Equity		371,178.07
TOTAL LIABILITIES AND MEMBERS' EQUITY		$ 418,587.92

The Accompanying notes are an integral part of this statement.

American Railway Engineering Association
Comparative Statement of Income and Expenses
Years Ending December 31,

	1985	1984
INCOME		
Dues	$ 132,460.98	$ 111,768.89
Publications:		
Bulletins	11,470.60	11,818.12
Proceedings	4,857.50	1,481.00
Manual	163,506.80	171,717.14
Portfolio	26,738.93	32,391.13
Miscellaneous	6,548.10	1,279.46
Advertising	34,267.13	30,362.50
Interest	24,258.98	32,059.15
Conferences	30,297.13	32,918.73
Miscellaneous Income	7,029.12	4,347.86
TOTAL INCOME	$ 441,435.27	$ 430,143.98
EXPENSES		
Cost of Publications		
Beginning Inventory	$ 68,669.50	$ 59,384.50
Manuals	24,426.28	47,062.59
Portfolios	3,785.35	8,535.72
Bulletins and Proceedings	103,011.56	68,239.61
	199,892.69	183,222.42
Less: Ending Inventory	45,782.00	68,669.50
Net Cost of Publications	154,110.69	114,552.92
Salaries, Taxes and Fringe Benefits	147,969.11	154,004.19
Stationery and Printing	4,754.27	3,603.59
Shipping and Phone	13,192.93	17,461.32
Supplies	1,619.12	1,704.69
Professor Expenses	7,104.86	7,708.85
Travel Expense	9,225.66	9,507.46
Conferences and Meetings	34,853.95	24,543.13
Audit	2,906.91	2,492.76
Temporary Help	4,985.94	4,215.96
Advertising	16,712.54	12,228.06
Subscriptions AREA Members	13,132.08	9,875.65
Dues and Subscriptions	1,525.00	1,290.00
Miscellaneous Office Supplies & Refunds	5,274.92	13,885.96
Insurance	1,917.80	1,417.80
Depreciation	2,024.82	1,169.17
TOTAL EXPENSES	421,310.60	379,661.51
EXCESS OF INCOME OVER EXPENSES OR (DEFICIT)	$ 20,124.67	$ 50,482.47

The accompanying notes are an integral part of this statement

American Railway Engineering Association
Notes to Financial Statements
December 31, 1985

NOTE 1. SIGNIFICANT ACCOUNTING POLICIES

Accounting Method - The association's books and records are maintained on the cash basis. The enclosed statements were prepared from the books after adjusting to the accrual basis.

Fixed Assets - Depreciation of furniture and fixtures is provided using the straight line method over the estimated useful life of each asset. Individual assets purchased for less than $500.00 are not capitalized.

Inventories - Inventories are stated at the lower of cost or market using the first in - first out method.

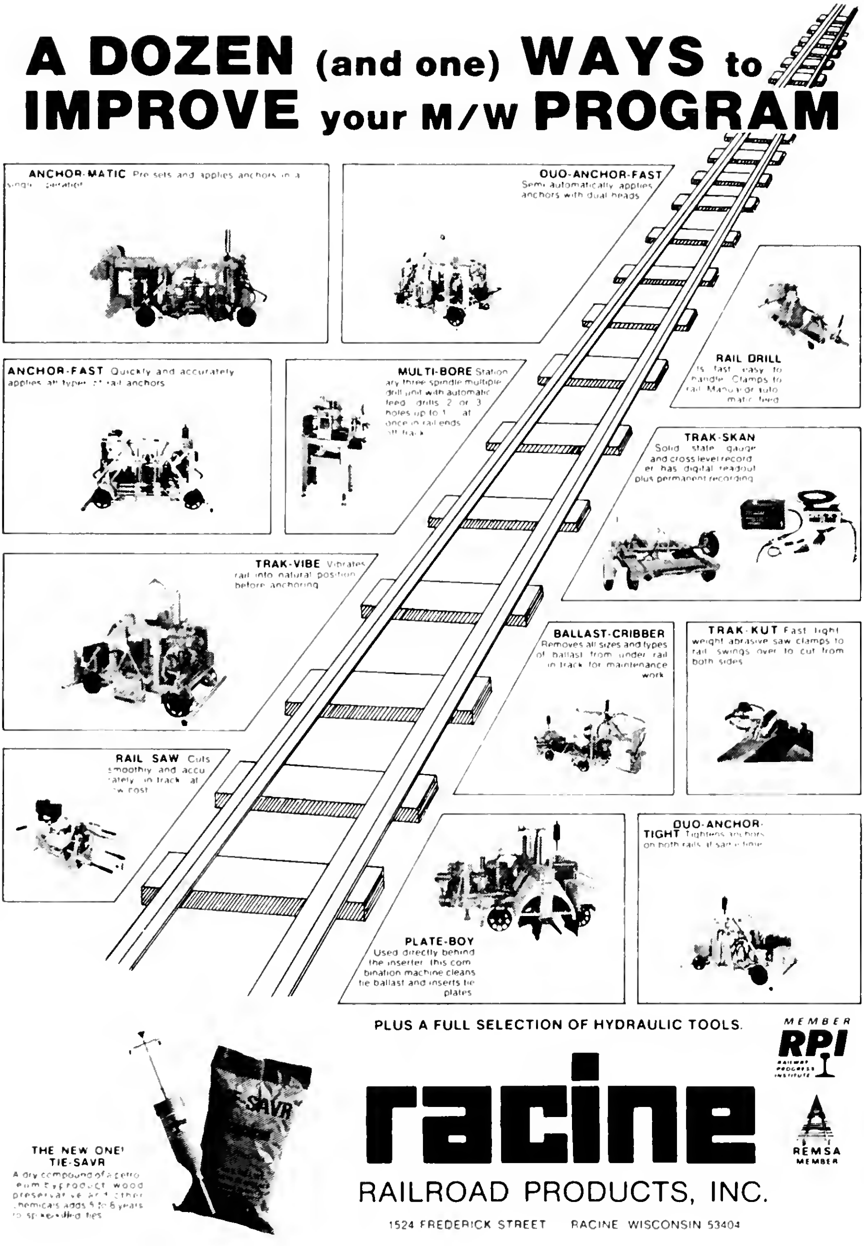
NOTE 2. INVESTMENTS

As of the balance sheet date, the Association's Investments are:

CERTIFICATES OF DEPOSIT	MATURITY	RATE	AMOUNT
American S & L Assoc. Stockton, CA	3/31/86	8.40%	$ 95,880.00
Riggs National Bank Washington DC	3/31/86	7.75%	90,000.00
San Jacinto Savings Assn. Houston, TX	5/12/86	9.00%	75,000.00
MUTUAL FUND			
Seligman Group			19,306.80
			$ 280,186.80

NOTE 3. FEDERAL INCOME TAX EXEMPTION

The association is exempt from federal income taxes under Internal Revenue Code Section #501(c) (6). Federal form 990 Return of Organization Exempt from Income Tax has been prepared in conformity with this report.


A DOZEN (and one) WAYS to IMPROVE your M/W PROGRAM
ANCHOR-MATIC Pre-sets and applies anchors in a single operation
DUO-ANCHOR-FAST Semi-automatically applies anchors with dual heads
ANCHOR-FAST Quickly and accurately applies all types of rail anchors
MULTI-BORE Stationary three spindle multiple drill unit with automatic feed drills 2 or 3 holes up to 1" at once in rail ends off track
RAIL DRILL Is fast, easy to handle. Clamps to rail. Manual or auto matic feed
TRAK-SKAN Solid state gauge and cross level recorder has digital readout plus permanent recording
TRAK-VIBE Vibrates rail into natural position before anchoring
BALLAST-CRIBBER Removes all sizes and types of ballast from under rail in track for maintenance work
TRAK-KUT Fast light weight abrasive saw clamps to rail, swings over to cut from both sides
RAIL SAW Cuts smoothly and accurately in track at low cost
DUO-ANCHOR-TIGHT Tightens anchors on both rails at same time
PLATE-BOY Used directly behind the inserter. This combination machine cleans tie ballast and inserts tie plates
PLUS A FULL SELECTION OF HYDRAULIC TOOLS.
MEMBER RPI
REMSA MEMBER
THE NEW ONE! TIE-SAVR
A dry compound of a petroleum byproduct, wood preservative and other chemicals adds 5 to 6 years to spike-killed ties
racine
RAILROAD PRODUCTS, INC.
1524 FREDERICK STREET RACINE WISCONSIN 53404

DIRECTORY OF CONSULTING ENGINEERS

NOTES

AREA

OCTOBER 1986

ROOM 7702
50 F St., N.W.
WASHINGTON, D.C. 20001
U.S.A.

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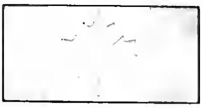 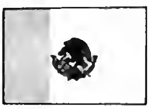 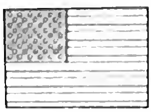

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1986-1987

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Manager—Headquarters

Judi Meyerhoeffer, 50 F St., N.W., Washington, D.C. 20001

Director of Engineering

W. Arthur Grotz, Jr., 50 F St., N.W., Washington, D.C. 20001

American Railway Engineering Association

Bulletin 707

OCTOBER 1986

Proceedings Volume 87 (1986)

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Cover photo: Eureka Southern Railroad Main Line in Eel River Valley south of Island Mountain, California.

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Preventing and Controlling Slope Instabilities

By

Dexter N. McCulloch
Shannon and Wilson Inc.
Seattle, Washington

Active slide area temporarily handled by means of slow order and periodic raising and lining

Editor's Introduction

The maintenance of railway operations through slide areas is a daily fact of life for many engineering officers, especially in the western United States and Canada. While some types of slides can be handled by a combination of careful inspection, slow orders, and periodic lining and raising of track, others pose the possibility of sudden massive movement. While the potential power and unpredictability of natural phenomena preclude any absolute assurance of slope stability in every situation, the following article can be of great help in understanding and minimizing the forces creating slope instabilities.

The photos above and on the cover were taken in the Eel River Valley in Northwestern California where officers and employees of the Eureka Southern Railroad successfully handled many slide situations set off or reactivated by unusually heavy rains early this year.

Preventing and Controlling Slope Instabilities

By

D. N. McCulloch

Excerpts from Presentation to 1986 Area Technical Conference, Chicago, Illinois, March 25, 1986

SPECIAL REQUIREMENTS OF RAILROADS WHEN A LANDSLIDE OR EMBANKMENT FAILURE DISRUPTS OR THREATENS TRAFFIC

- Get track back in service. Start remedial measures as soon as equipment can be mobilized.
- Minimize slow orders or traffic delays while stabilization work is completed. Avoid prolonged slow orders.
- Maximize use of railroad personnel and equipment to expedite repair.
- Make use of available resources and materials to expedite repair.
- Avoid "overkill" in solution to stability problem.

TYPES OF RAILROAD SLOPE FAILURES*

SLIDES THAT COVER TRACK

- Dangerous - may cause derailments if not discovered in time.
- Need to clear track removes toe of slide and may cause slide enlargement and acceleration. Slide may therefore continue for a long period with much traffic delay and prolonged slow orders. Costly maintenance.

SLIDES THAT CUT OR DEFORM TRACK

- Most dangerous - likely to cause serious derailments if not discovered in time.
- Can require repeated addition or removal of ballast and realignment. Costly maintenance.
- Can require prolonged slow orders.
- If track is heaved by slide, maintenance can be very costly.

* Does not include debris avalanche, rockfall, or washout.

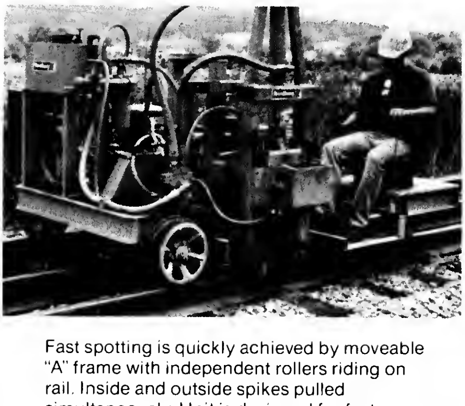
Got spike pulling problems at joints?

See it on video... Call your Nordberg representative

Use the New Nordberg "claws" spike puller.*

Specially designed pulling arms allow new spike puller to go through rail joints without slowing down. Spike pulled straight for reuse. Line and anchor spikes easily pulled without changing pattern.

*Patent Pending

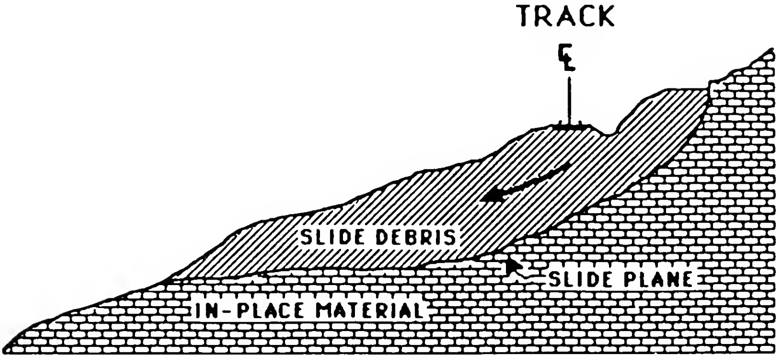


Fast spotting is quickly achieved by moveable "A" frame with independent rollers riding on rail. Inside and outside spikes pulled simultaneously. Unit is designed for fast, easy accessability to all working parts.

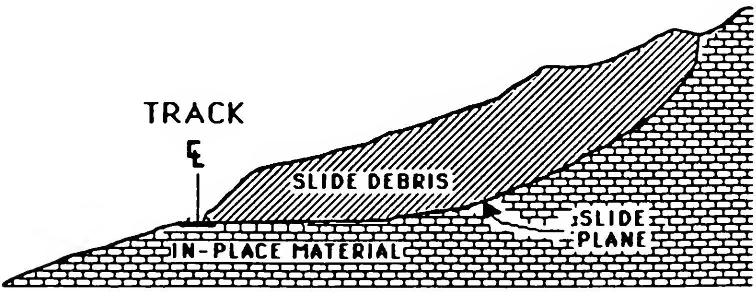
Well-organized operator's station allows high visibility to pulling operation. Exclusive "trigger" with fingertip control permits a continuous spike pulling operation and special "claw" makes grasping simple and fast.

Contact your nearest representative for literature, or write: Rexnord Inc., Railway Equipment Division, P.O. Box 1562, Milwaukee, WI 53201 Telephone (414) 769-4600

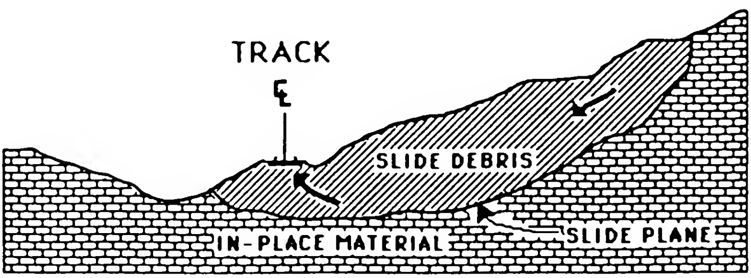
Rexnord



SLIDES CUTTING TRACK



SLIDES COVERING TRACK



SLIDES HEAVING TRACK

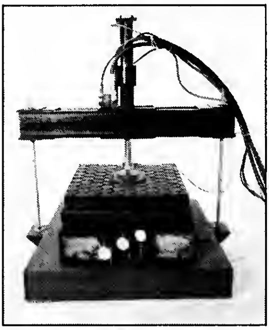
OMNI®

SHIMLESS FULL DEPTH RUBBER CROSSING SURFACE

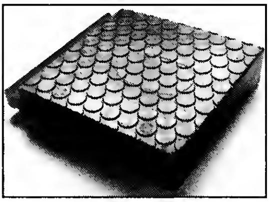
Meeting The Challenge of Relentless Loadings

The Oregon Transportation Research Institute (OTRI) at Oregon State University recently tested the OMNI Panel for fatigue resistence and shock absorbing durability. Dr. Gary Hicks, OTRI Director, reported these outstanding results.

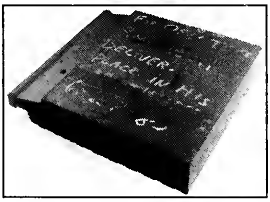
Test Background



6.1 million accelerated loadings were applied to the OMNI Panel. Each loading equal to the ground pressure applied by the tire of a 80,000 lb. gross loaded truck. The net effect equal to 36 to 48 million loadings under normal traffic conditions.*



After this test, the OMNI Panel showed no signs of fatigue...Only the faint outline of the oval, steel pressure plate that pounded directly on the Panel after the plate's rubber "shoe" wore off.



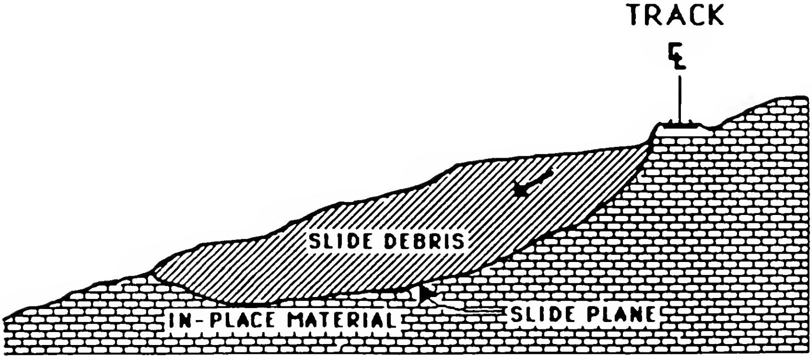
The Panel was secured to standard ties during the test using a normal pattern of Camcar drive screws. After the test, the bottom of the Panel showed no wear from panel movement nor did the tie surface. Grease pencil markings in the contact area between the Panel and tie were still legible after testing.

The Conclusion

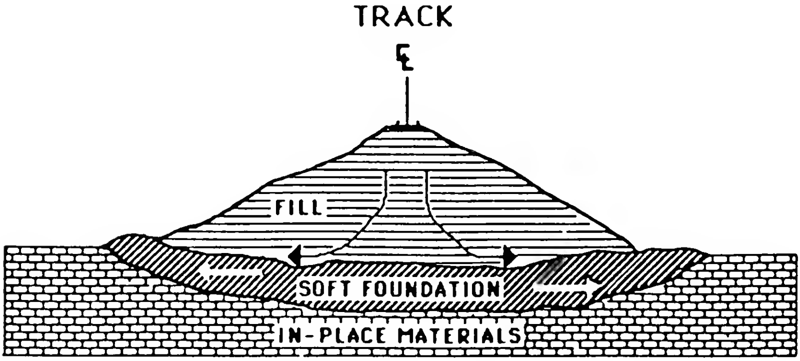
The OMNI Panel provides high performance under demanding conditions. It is far superior to steel, asphalt or wood in its shock absorbing characteristics.

OMNI® RUBBER PRODUCTS, INC.
P.O. Box 2788
Portland, OR 97208-2788
(503) 287-9860

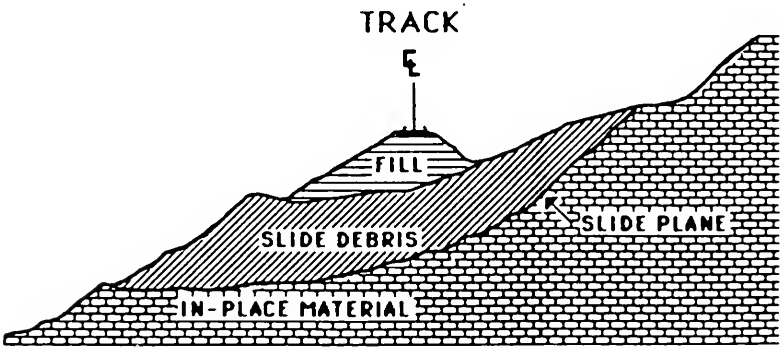
*Recent research by the Pennsylvania DOT indicates that only 7 to 9 million trucks will pass over an average high-use crossing in 20 years.



SLIDES THREATENING TRACK



BASE FAILURE



REACTIVATION OF OLD SLIDE

CAUSE OF MOST FAILURES

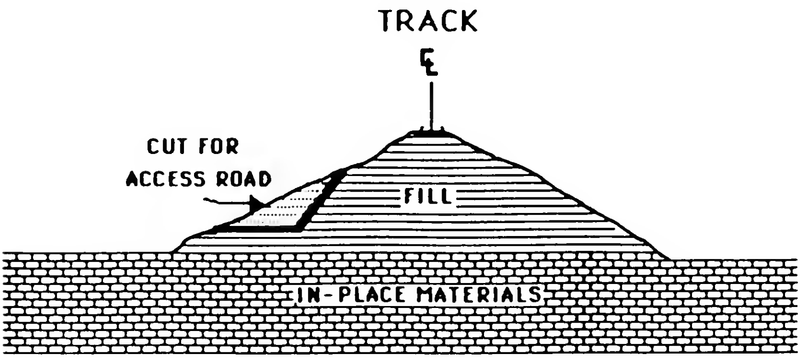
- Most landslides or embankment failures are caused by one or more of the following three situations.

  1. Removal of supporting material from the toe of the slope by man or natural causes (i.e., river eroding toe).

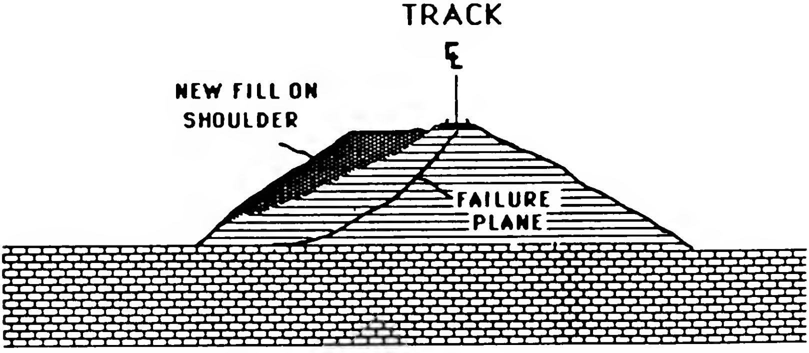
  2. Overloading or oversteepening of slopes by filling operations.

  3. Buildup of excessive water levels in the slope. This can occur naturally from the heavy rains or spring snowmelt or can be man induced by land development, irrigation, or other drainage changes.

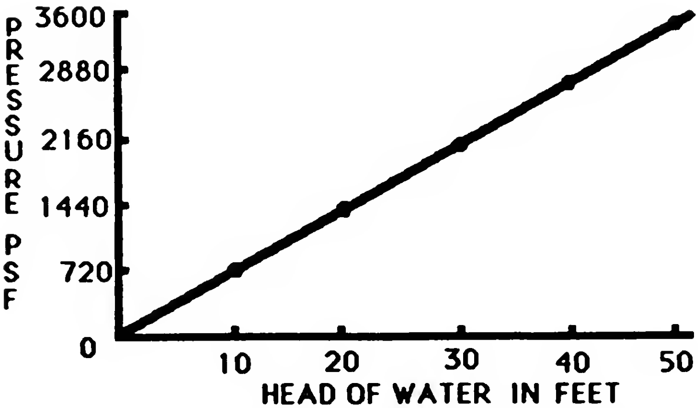
- Of the three frequent causes listed above, buildup of water in the slope is the most common.



REMOVAL OF TOE



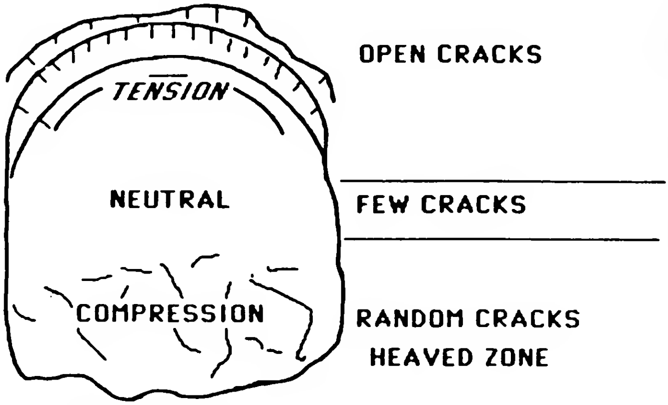
OVERLOADING / OVERSTEEPENING
OF SLOPE



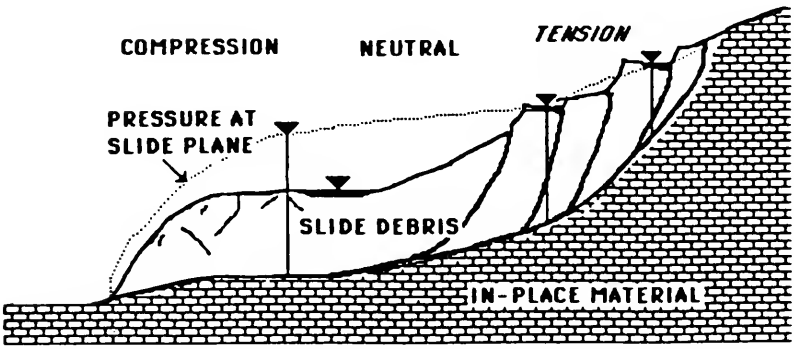
UPLIFT PRESSURE VS. HEAD

SOURCES OF WATER

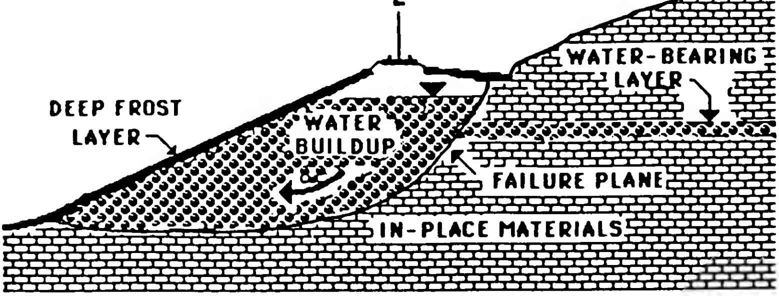
- BLOCKED SURFACE DRAINAGE
- RUNOFF AND PRECIPITATION
- DRAINAGE FROM UPLAND DEVELOPMENT
- FROST BLOCKAGE OF DRAINAGE FROM TOE OF FILL OR SLOPE
- BLOCKED DRAINAGE BLANKETS IN FILLS
- SPRINGS



ANATOMY OF A SLIDE



WATER PRESSURE AT SLIDE PLANE



BLOWOUT

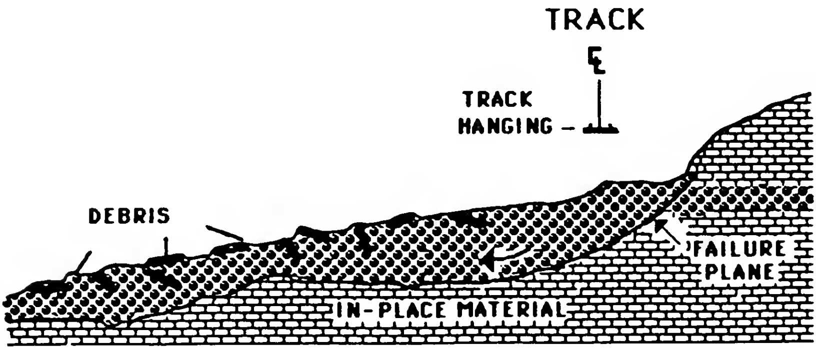
ITT

SEL Canada
A Division of ITT Industries of Canada Ltd.
180 Duncan Mill Road, 3rd Floor
DON MILLS, Ontario, Canada
M3B 1Z6

Telephone: (416) 445-8600
Telex: 06-986112 Selcan Tor

General Manager: Karl U. Dobler
Director of Marketing: Walter Friesen

PRODUCTS: ITT (SELC) provides turnkey signalling systems for streetcars, subways, AGT systems and heavy rail. ITT (SELC) designs/manufactures and installs all major components, e.g. centralized traffic control systems; SELCOM remote control systems (vital and non-vital); INTERSIG micro-processor based interlocking systems; SELTRAC automatic train control systems; SELTRAIN advanced train control systems; Transponders; ICOM inductive transmission systems; VIDAC vital communications controllers; Wheelcounters; Automatic Train Stops; Switch Machines and decentralized LRT control logic for automatic routing, pre-emptive signalling and gate crossing control.



BLOWOUT

RAPID STABILIZATION MEASURES

- Two stabilization methods are particularly adaptable to the railroad environment, 1) trench drain installation and 2) toe reconstruction/regrading. Each of these can make use of air-dump cars for importation or removal of material from the failure area. Imported materials may be clean railroad ballast for use as a drainage medium in the trench drains or other granular materials for slide toe reconstruction. These materials are generally found where existing loading facilities make their use practical if haul distances are not great. If the track is not buried or excessively out of line, either method can be accomplished while the track remains in service. Under normal circumstances, with small to medium (5,000 to 40,000 cubic yard) landslides, remedial measures can be accomplished within a few days without significant traffic delays. In one case a very large slide (1,500,000 cubic yards) was stopped by installation at about 1000 feet of trench drain.

- Two other alternatives that may be applicable are 1) slide removal and 2) line change to avoid slide.

- On arrival at the slide site we evaluate the situation, estimate the depth of sliding, and develop our opinions as to the causes or cause of sliding. We recommend a course of action and types of equipment, personnel, and materials needed to begin the stabilization measures. Surface drainage (if warranted) is started immediately while equipment and materials for deeper drainage are mobilized.

- For slides that cover or heave the track, drainage is usually the most effective and rapid solution. Most of the time trench drains, excavated by a hydraulic backhoe, and backfilled immediately with free-draining granular material (clean ballast or sand and gravel) have proven to be a quick and effective method of controlling slide movement. The layout of the trench drains is dependent on the configuration, depth and mobility of the slide mass as well as water conditions within the slide. Observations made during trenching are used to evaluate the adequacy of the drainage work. Two front end loaders are normally used to move the drainage material to the trench location. If the ground is very soft and mobility poor, then

mats can be used to support the backhoe. The loaders will run on the granular backfill. In this way work can be accomplished on very soft, unstable ground conditions.

- For slides that cut the track, and displace the track structure down and out, a combination of drainage and slide toe reconstruction is generally most effective. A deep culvert or bored pipe may be needed to carry collected water beneath the track structure. A buttress can be constructed rapidly (if the terrain makes this practical) by using a work train with air dumps to transport materials to the site. Two bulldozers and a large backhoe are normally sufficient to move the material and reconfigure the slide toe.

RAPID DRAINAGE MEASURES

- SURFACE DRAINS
  REMOVE PONDED WATER
  DEEPEN SURFACE DITCHES

- TRENCH DRAINS
  REDUCE PRESSURES IN SLIDE
  PREVENT CRITICAL PRESSURES

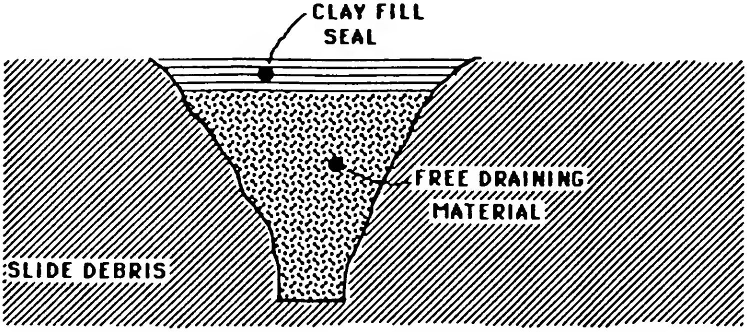
TRENCH DRAINS

- EXCAVATE WITH BACKHOE
  CATIPILLAR 215 TO 235 OR EQUIVALENT

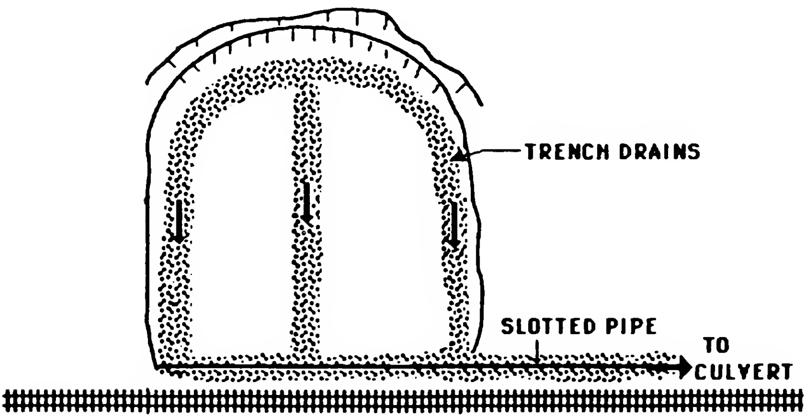
- BACKFILL WITH CLEAN GRANULAR MATERIAL

- USE BUCKET LOADERS TO PLACE BACKFILL

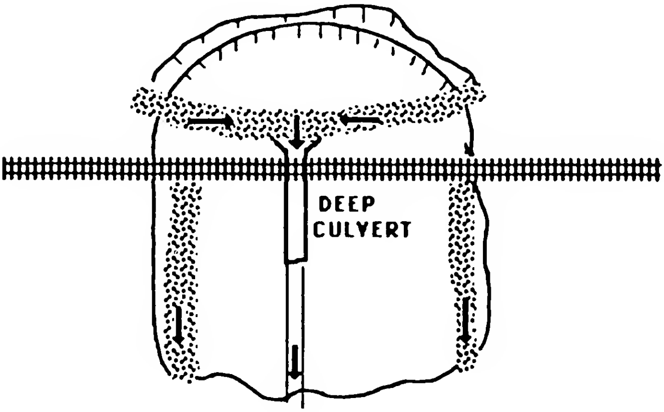
- TRANSPORT BACKFILL TO SITE WITH AIR-DUMPS



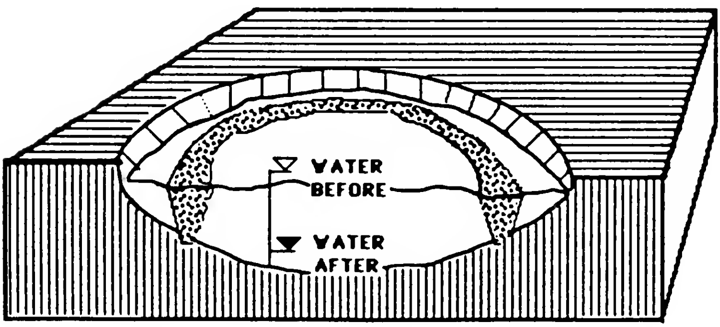
TRENCH DRAIN



TRENCH DRAIN LOCATION
SLIDE ABOVE TRACKS

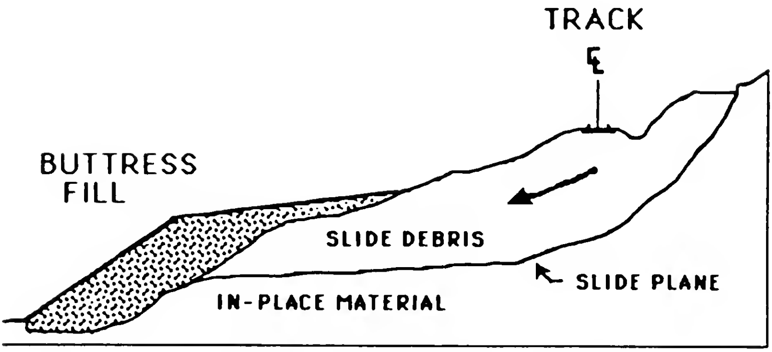


TRENCH DRAIN LOCATION

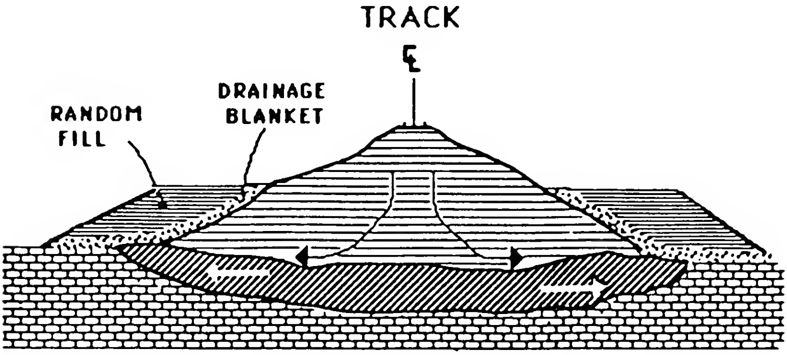


TRENCH DRAIN EFFECTS
LOOKING INTO SLOPE

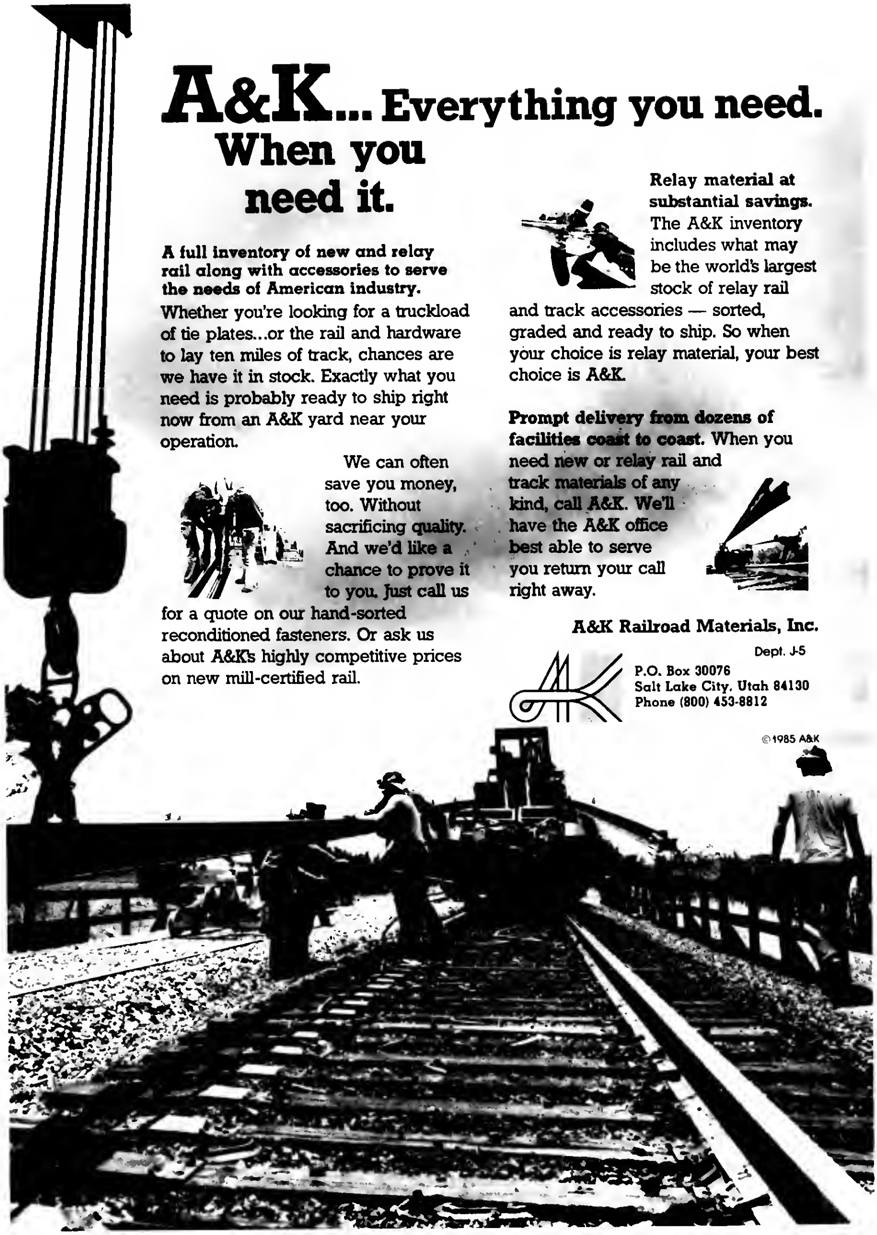
TOE LOADING



SLIDES CUTTING TRACK
TOE BUTTRESS



BASE FAILURE
STABILIZING BERMS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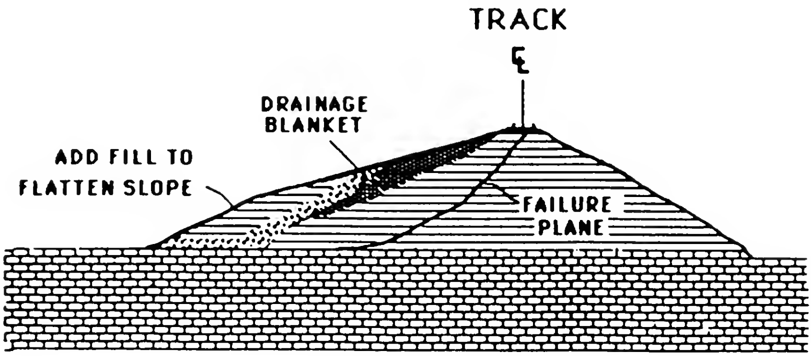

SLOPE FLATTENING

OTHER STABILIZATION METHODS

- In special situations other stabilization methods may be needed to control a slide. Some of these methods are 1) drilling of horizontal drains into the slide mass, 2) construction of retaining walls, 3) reconstruction of the embankment using reinforced earth construction techniques, and 4) in very special cases, drainage tunnel construction. These methods are generally slow to implement and relatively costly and would normally be considered only as a "last resort".

SLOPE STABILITY STUDIES

- In some cases it may be prudent to perform test drilling, groundwater monitoring, and other information gathering at the failure site. This information can be used to perform stability analyses which aid in judging whether or not sufficient remedial work has been done or is planned for control of the failure.

- Since the most important consideration in the railroad environment is restoration or maintenance of live track conditions, these studies (when needed) are usually accomplished after the emergency remedial work is done and the slide is stable.

COSTS FOR RAPID STABILIZATION MEASURES

- Cost for slide stabilization obviously can vary greatly depending on circumstances. The size, slope, depth, groundwater and slide mass conditions, location, and position of the track structure relative to the slide all influence the cost.

- Trench drains about 15 feet deep can be installed for about $25 per lineal foot. This may be higher due to haul costs, material cost variations, and productivity of personnel and equipment.

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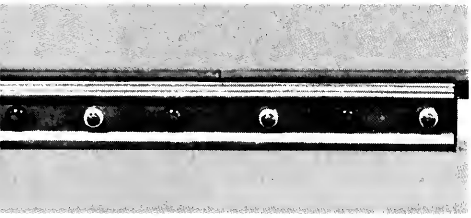

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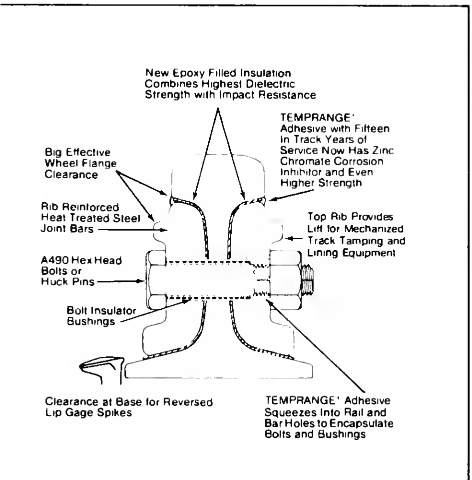

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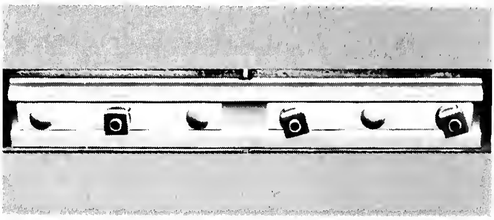

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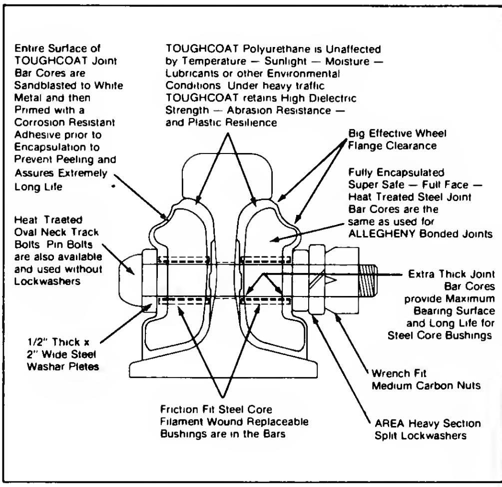

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- For a slide of dimensions of about 200 feet wide, x 200 feet long, x 20 feet deep, about 500 to 800 feet of drainage is usually adequate. This drainage can normally be installed at a rate of about 200 feet per shift.

- Cost for slide toe modifications or rock buttress construction can also vary substantially depending on cost of suitable materials, haul distance, quantities, availability of loading sites for air dumps, and work train costs. However, this type of work usually can be done rapidly and is therefore usually very cost effective. Example: 60 carloads of rock (3000 cubic yards) were placed in a 10 hour day using 4 air dump cars, 2 dozers and a backhoe. The slide in this example quit moving as soon as the material was placed.

CONCLUSIONS

- Rapid control of most railroad landslides is possible

- Work can be done without undue interference with traffic

- Drainage and slide toe reconstruction are well suited to the operational needs and facilities of railroads

- Slide control need not be too costly

    - Most Maintenance-of-Way departments have the necessary operators and equipment

    - Work can be done without outside contractors at the railroads schedule

- Control methods involving costly construction or prolonged evaluation are a "last resort".

Developments in Railroad Rail

R. K. Steele * and D. H. Stone**

Presentation to 1986
AREA Technical Conference
Chicago, Illinois, March 23, 1986

INTRODUCTION

Ever increasing traffic density and wheel loads press rail harder to meet acceptable performance requirements. In response to the need for improved performance, advances have been made in the metallurgy of rail and in the manner in which it is used and maintained. The trend has been toward the use of higher strength rails which have superior resistance to wear, metal flow, corrugation, and defect formation. This paper will describe some of the advances which have been made in recent years, as well as some of the problems which have persisted. Several new innovations and potential approaches which have not yet reached the stage of application also will be mentioned.

HEAT TREATMENT

The AAR has undertaken a program to develop a process for the continuous heat-treatment of rail. The nature of this process makes it possible to heat-treat strings of continuous welded rail (CWR). This has the effect of homogenizing the weld and heat-affected-zone which eliminates the hardness gradient across the weld. This uniform hardness eliminates weld batter associated with existing welds in CWR.

The experimental rail heat-treatment test program was conducted in the pilot test facility described, in detail, in Reference 1. The process consists of in-line pre-heating, final heating to a uniform 1550°F temperature and quenching in a polymer alcohol-water spray. Results of initial trials determined that a high strength rail could be produced which exceeds the hardness requirements of the AREA specification for high-strength rail.

However, some of the rails produced in the initial trials had untempered martensite at the tips of the base flange which caused the rail to fail the drop test. A second test series was conducted in which the rails were tempered after quenching to eliminate the martensite. After tempering, test rails were able to pass the drop test. Additionally, when subjected to a web crack impact test, these rails exhibited the best results of any rail type tested, indicating a combination of excellent toughness and low residual stress.

An additional benefit of this process is its ability to treat second hand rail. If the rail is crack free, its fatigue life will be completely renewed.

An economic analysis of this process indicates a cost of $20-$50/ton of rail treated depending on yearly tonnage desired. This compares quite favorably with the $150-$200 per ton premium on commercially available high-strength rails.

Currently, a 1000-foot string of this rail is undergoing service trials on the Santa Fe Railway at the summit of Cajon Pass. The rail is on the high side of a 5° curve with a two inch superelevation. To date, an excess of 20 MGT of traffic has passed over the rail with negligible lubrication. The string contains 22 new and six used rails. Of the six used rails, three had old weld joints that were present prior to heat-treatment. The welds made after heat-treating show metal flow on the running surface typical of other high-strength rail weld joints, Figure 1. However, as expected, the welds in the rail prior to heat-treatment show no metal flow indicating neutralization of the heat-affected-zone. Under the above conditions, standard rail would be expected to have worn equivalent to 20 percent of its life. The test rails have shown little or no wear to date.

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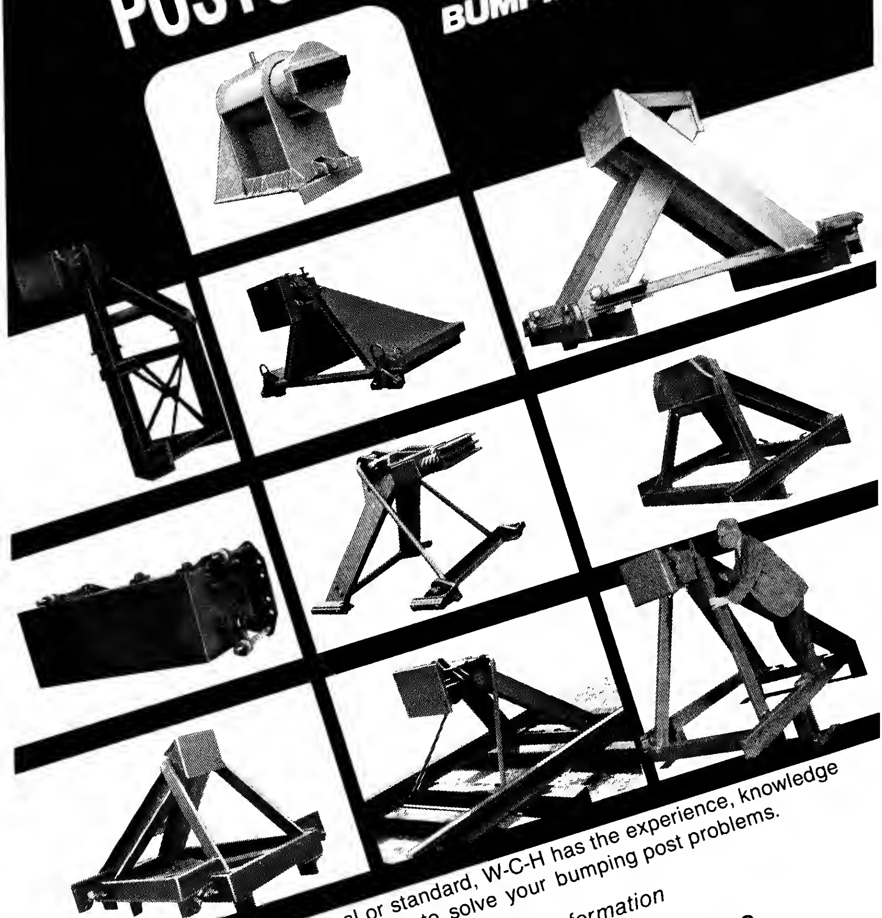

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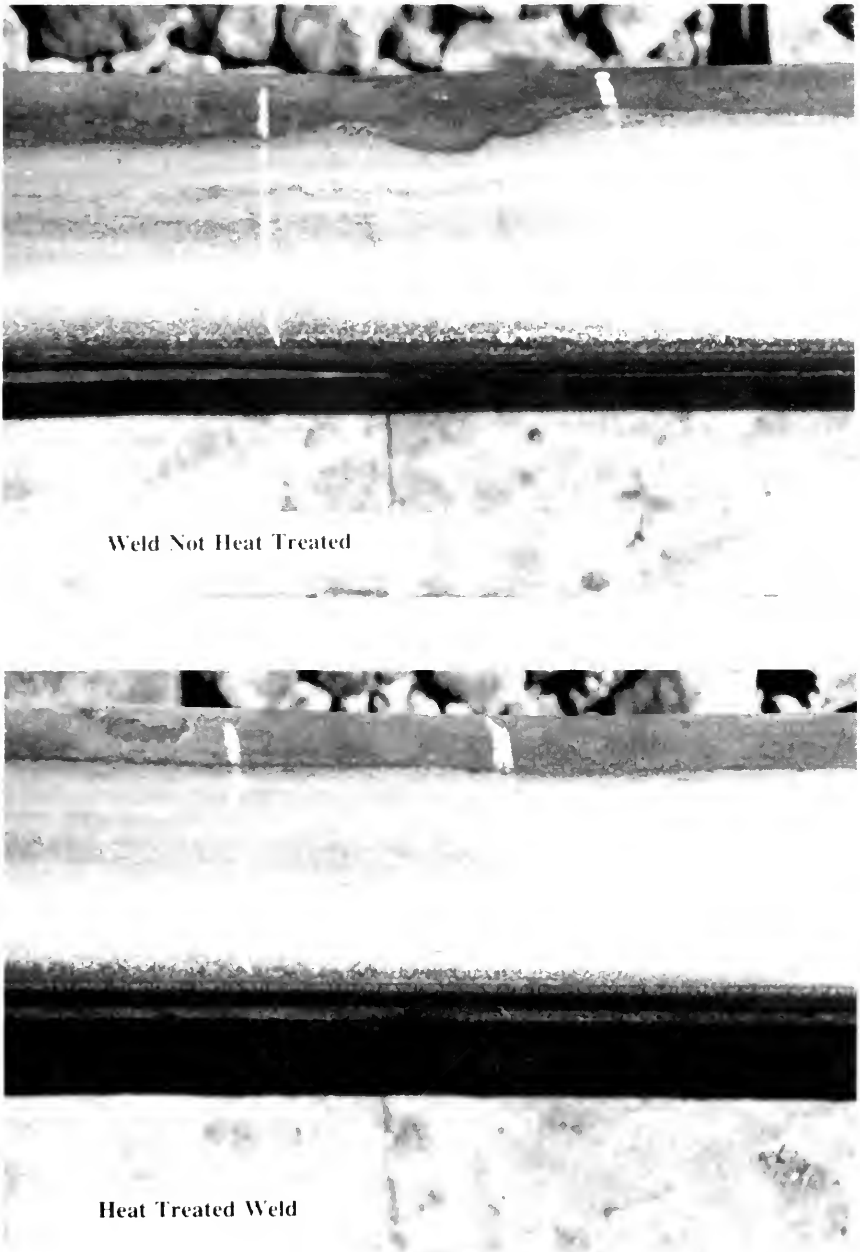
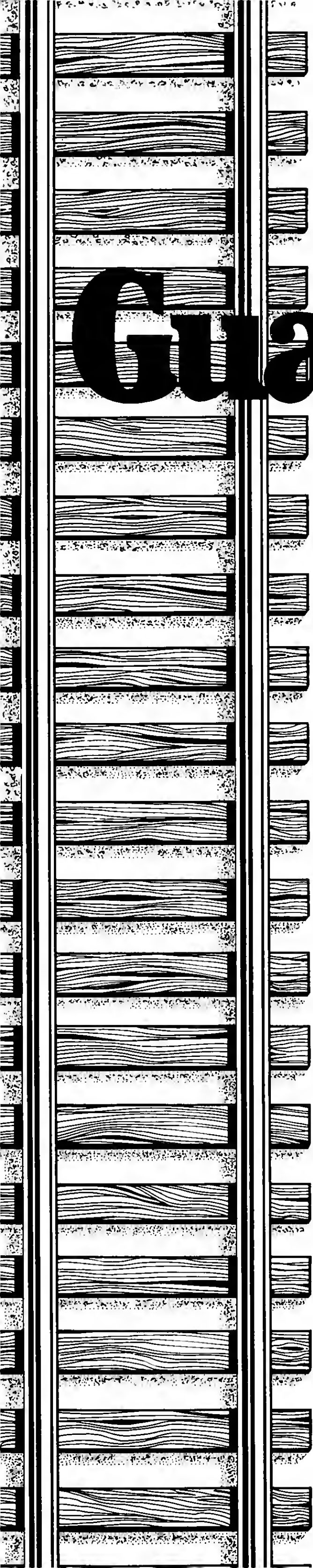


Figure 1. Illustration of Weld Batter at Non Heat Treated Weld and Absence of Batter at Heat Treated Weld.



Progress on the project has been made to the extent that it is proposed that the system be enlarged and modified for the conduct of pilot trials at a rail welding facility. The following improvements to the existing system are proposed:

1. Replacing the ceramic lining of the existing furnaces,
2. Construction of an additional furnace for tempering,
3. Extending the existing quenching system,
4. Engineering, design and construction of a guide/restraint system through the quenching system to ensure acceptable straightness,
5. Construction of material handling system to transfer quarter-mile strings from the welding line to the heat-treating line and a drive system for moving strings through the heat-treating system, and
6. Site preparation and movement of the system to a cooperating railroads welding plant.

Another project for the development of continuously heat-treated rail is underway in Canada. The project is developing a continuous induction head hardening treatment. While details of the progress of this project are unknown, it has been reported that no straightness problems have been encountered (2).

An advantage of heat-treated rail is that it may be joined with no modification of standard flash butt welding procedures. However, a softened zone will be produced across weld which will batter under traffic. Australian researchers have developed and put into practice a simple, but effective, device for restoring a uniform hardness across the weld (3,4). An air quenching rig, as shown in Figure 2, directs air on to all sides of the head. Air quenching begins as soon as possible after welding and shearing in order to obtain maximum hardening. The shearing and rail moving operations usually take 50-70 seconds, and

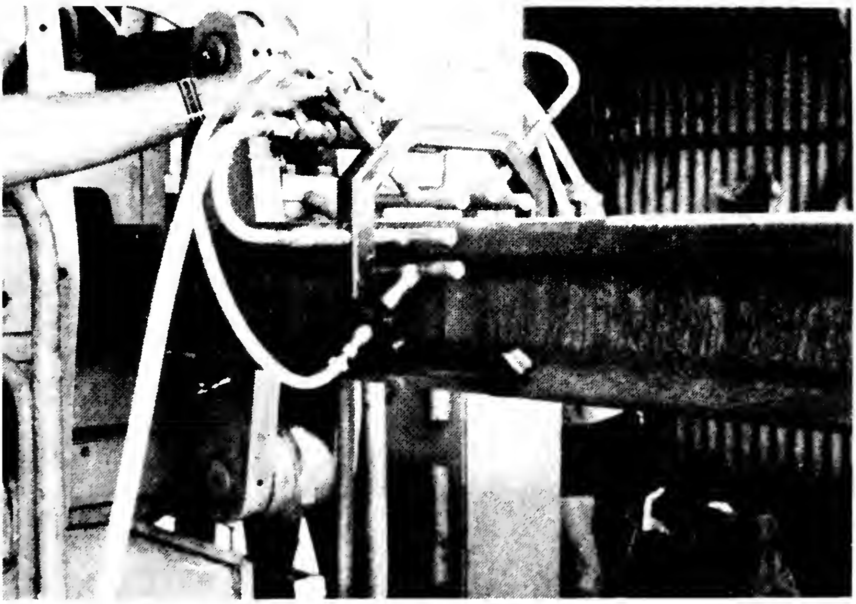


Figure 2. Air Quenching Apparatus for Electric Flashbutt Welds (Ref. 3).

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Or for track sweeping applications, use the magnet attachment for pick-up of spikes, joint bars, plates and other steel pieces.

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quenching is then applied for a further 90 seconds. The effect on productivity is not great and high hardness and wear resistance are maintained across the joint as shown in Figure 3.

Both heat-treating and alloying of conventional rail steels improve strength and hardness by producing a finer pearlite microstructure than that of conventional rails (5). However, the act of reheating to a lower temperature than the final rolling temperature imparts a finer grain size to the reheated portions of heat-treated rails. The finer grain size produces a steel of higher toughness or greater resistance to fracture (6).

ALLOY RAIL STEELS

Producing high-strength rail steels by alloying has as its advantage a low capital cost to the producer. Presumably, this gives alloy high strength rails an economic advantage over heat-treating. However, alloying can cause a decrease in weld production due to the necessity to add pre- or post-heating cycles.

Additionally, individual alloys in combination with producer to producer processing variations may bring forth some undesirable rail behavior. As an example, let us examine the puzzling behavior of

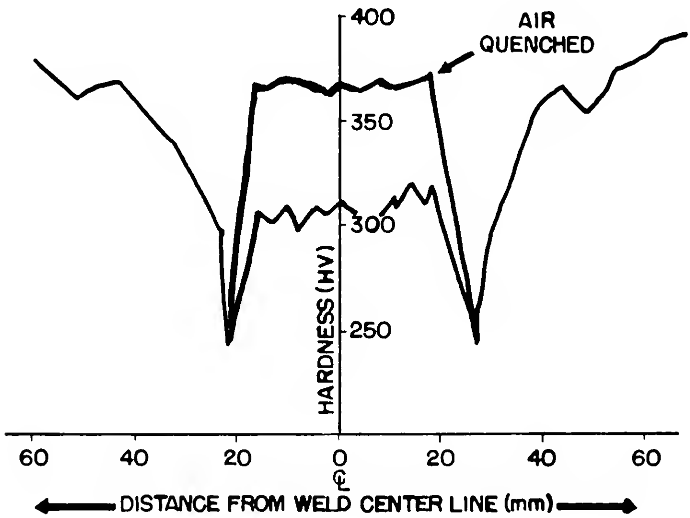

Figure 3. Effect of Air Quenching on Hardness of Head Hardened Rail Weldment (Ref. 3).

chromium-vanadium alloy rails. The AAR has evaluated twenty-two different rails, representing a wide spectrum of standard, heat-treated, and alloy rails, using a full section impact test as shown in Figure 4.

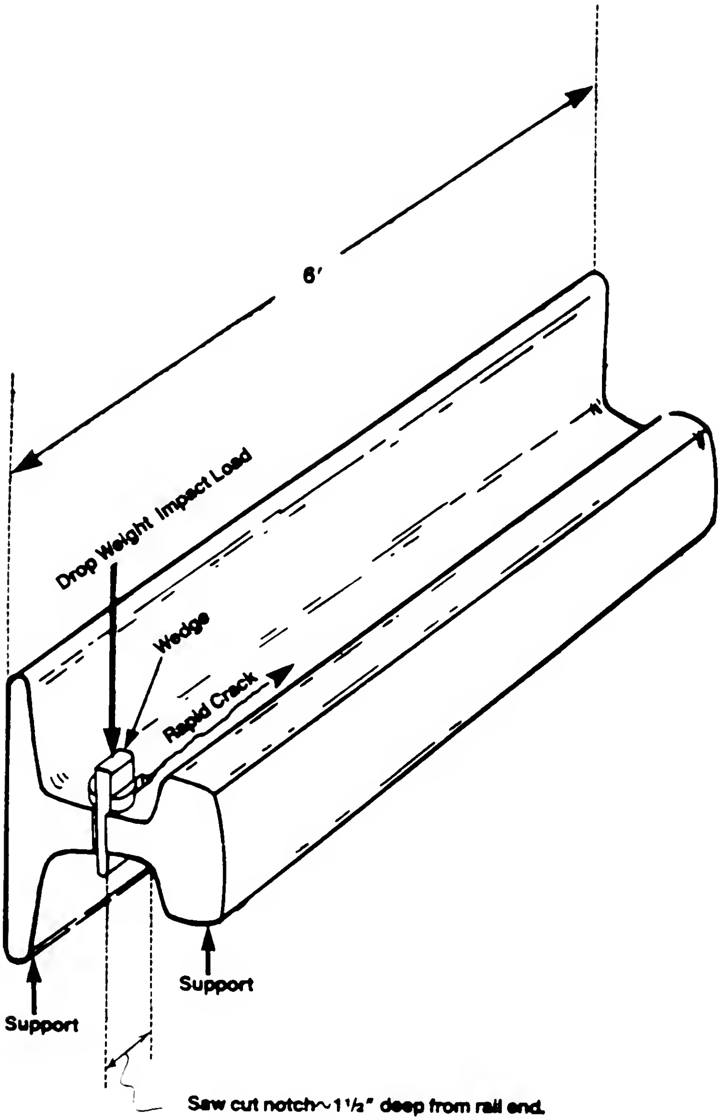

Figure 4. Full Rail Section Drop Weight Web Crack Propagation Test.

The results for these 22 tests show (Figure 5) that one manufacturer's roller-straightened Cr-V rails produce long web cracks as compared to another manufacturer's Cr-V rails which were gag-straightened

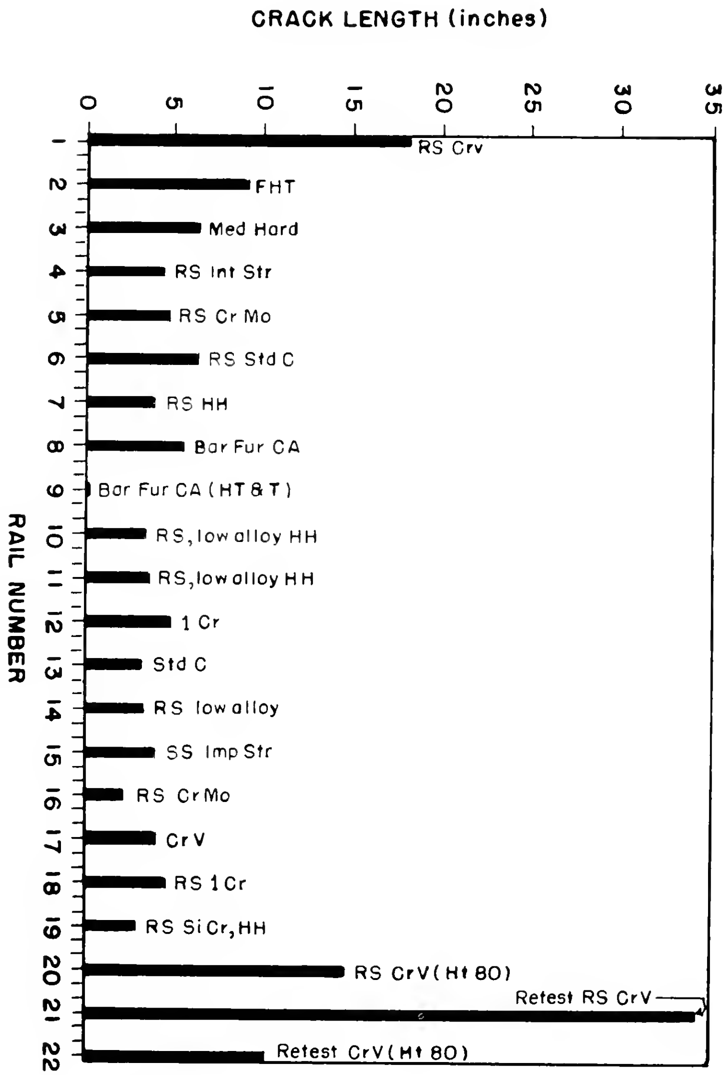

Figure 5. Web Crack Lengths of Various Rails.

when compared to all other rails tested. Figure 6 illustrates the results of some small specimen crack arrest tests and shows no significant difference in any of the steels tested. Residual stress tests and calculations

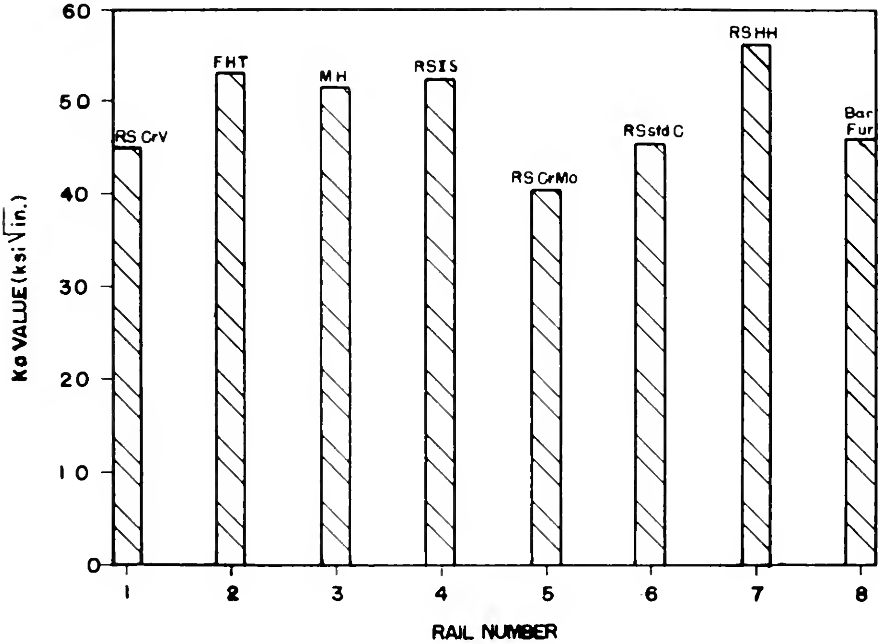

Figure 6. Laboratory Specimen Crack Arrest Toughness.

show that Cr-V rails that had long cracks had relatively high levels of residual stress, but some of the Cr-Mo rails had much higher residual stresses yet did not produce long cracks. It appears that vanadium alone does not cause the tendency for rapid, long web crack growth, nor does residual stress alone produce long cracks. The behavior of one manufacturer's Cr-V rail may depend upon both the material rate sensitivity and residual stress together.

HEAT-TREATED ALLOY RAILS

The Australians and Japanese have recently produced *microalloyed* head-hardened rails which have hardnesses in the 380-410 Brinell range. The improvement in mechanical properties may be achieved by either of the following practices (7): microalloying with columbium and/or vanadium to achieve a finer pearlite together with *precipitation hardening* of the ferrite or, microalloying with silicon and chromium to achieve finer pearlite together with *solution hardening* of the ferrite. The resulting increase has been shown to produce a rail of superior resistance to compressive plastic flow (7) as shown in Figure 7.


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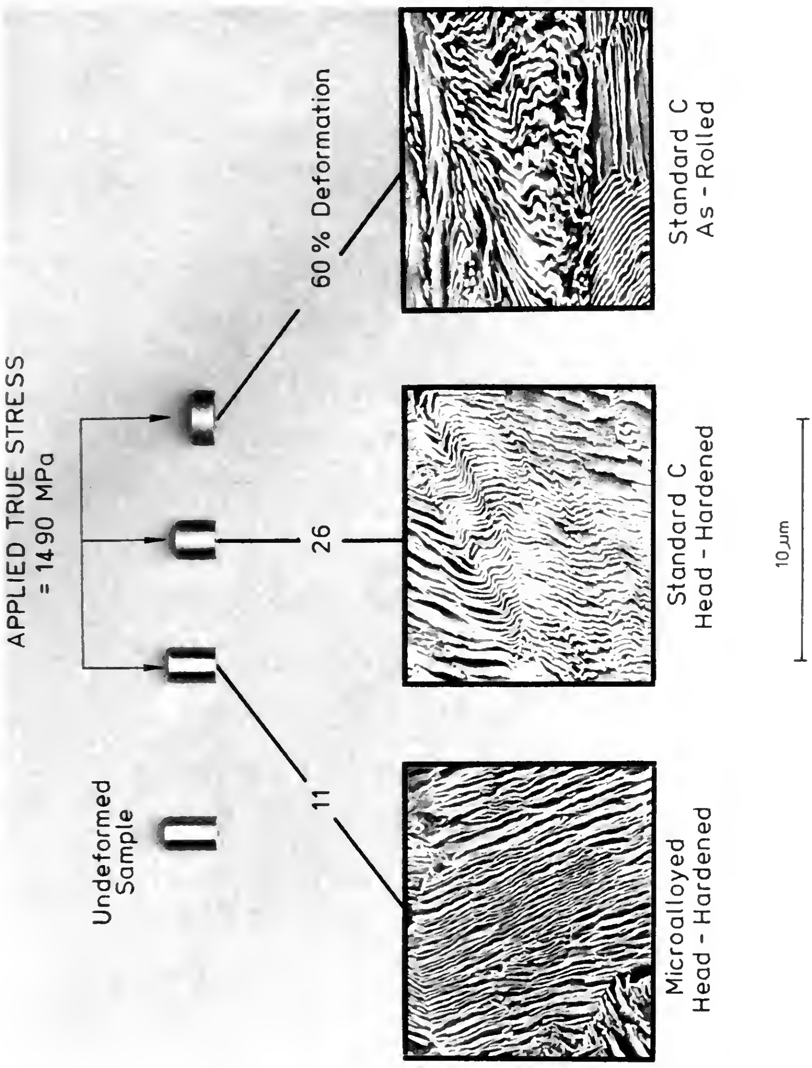


Figure 7. Comparison of Compression Deformation of Three Rail Steel Materials (Ref. 7).

OTHER CONSIDERATIONS

Efforts to improve the performance of railroad rails have sought primarily to refine the pearlite interlamellar spacing with an ensuing increase in hardness. However, recent laboratory studies by Kalousek et al. (8) have shown (Figure 8) that once the hardness of pearlitic rail steel reaches 38 R_C, virtually no further improvements in wear resistance will obtain from further increases in hardness. Both tempered martensite and bainite microstructures offer far less wear resistance than does pearlite. Other investigations (9) (10) have shown similar poor wear behavior for non pearlitic microstructures. The problem of obtaining satisfactory wear resistance with high hardness pearlitic microstructures appears to be related to the loss of long range laminarity as hardness increases.

Yet recent studies in Britain (11), Germany (12), and Australia (13) have shown that *low carbon* bainitic/martensitic steels can be prepared which have comparable strength and wear characteristics to conventional carbon steels. Illustrative properties are shown in Table I. The fatigue behavior of a carbide free bainitic steel is illustrated in Figure (9) in comparison with a conventional pearlitic rail steel. This particular composition has been introduced into commercial application as a cast crossing material; it can be produced in wrought form as well.

As wheel loads and traffic density have increased, concern has grown about fatigue defect initiation in rail. This has been especially true for shell/detail fracture types of defects, the formation of which is sensitive to wheel/rail contact stresses. The fact that shells are associated with non-metallic inclusion content has been reported many times (14) (15) (16). The results of X-ray dispersive examination of an inclusion in close proximity to a shell surface are shown in Figure 10. The inclusion examined is a calcium aluminate. Laboratory tests have been made establishing the fatigue life distributions of several rail steels having different inclusion contents (17). But it is not clear whether the apparent beneficial effects of reduced inclusion content on life is really due to cleanliness or to higher ultimate tensile strength (Figure 11). Thus, at this moment, the quantitative relationship between fatigue life and inclusion content for pearlitic rail steel is not well defined.

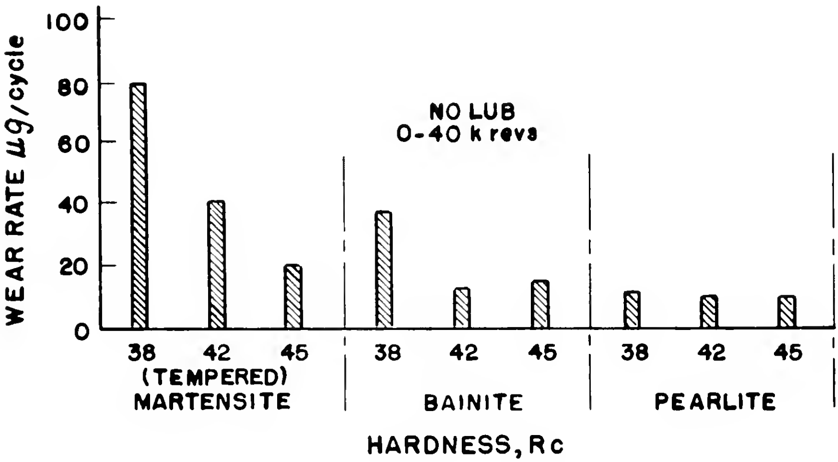


Figure 8. Laboratory Wear Rates of Rail Steel at Different Hardness Levels and with Different Microstructures (Ref. 8).

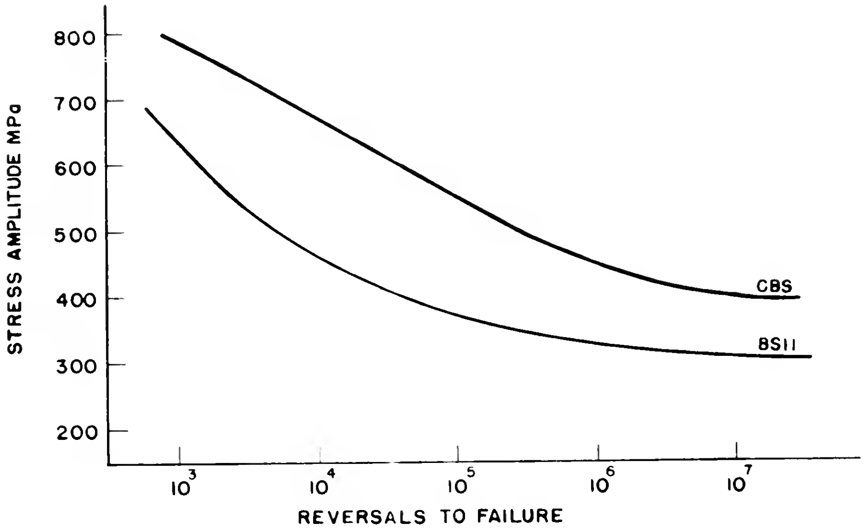


Figure 9. Fatigue S/N Curves for Cast Bainitic Steel (CBS) and BS11 Rail Steel (Ref. 11).

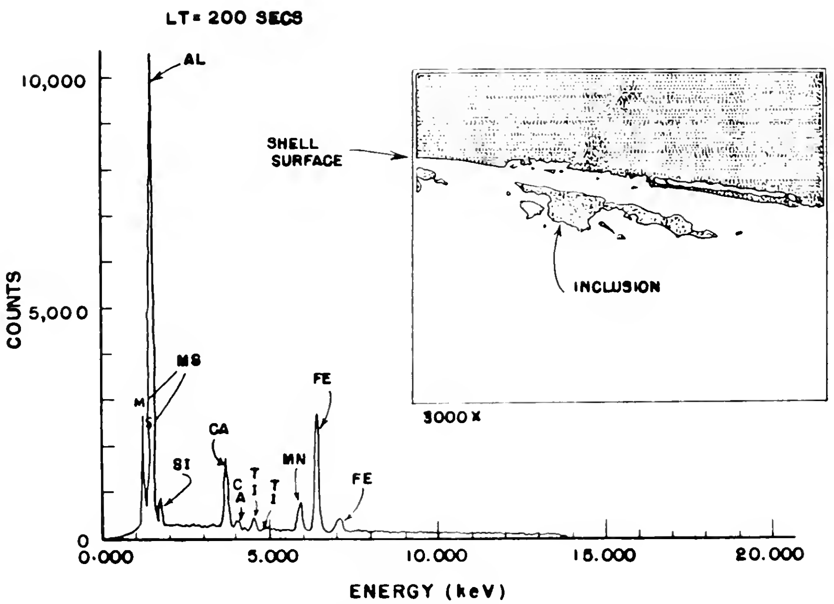


Figure 10. Scanning Electron Microscope EDX Analysis of an Inclusion Under a Shell Surface (Ref. 16).

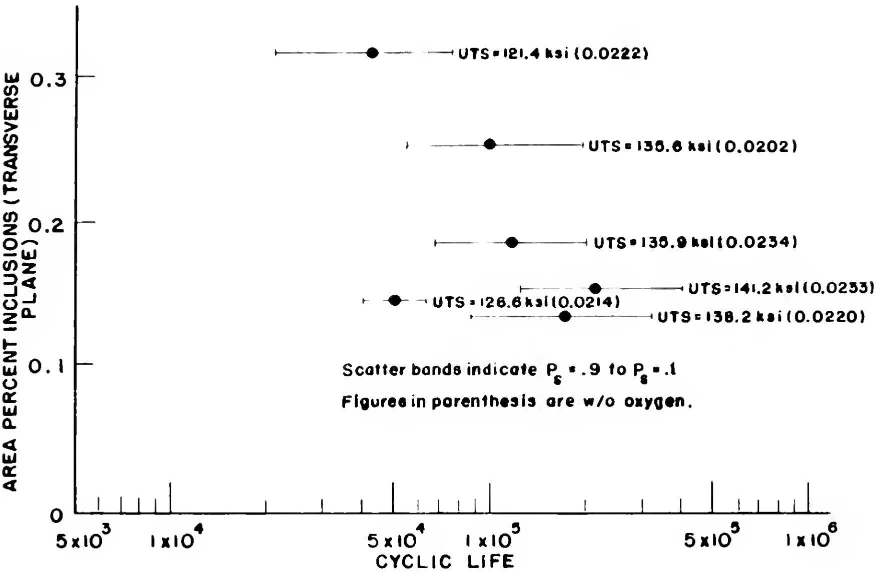


Figure 11. Apparent Variation of Fatigue Lives at 65 ksi (R = -1) with Area Percent Inclusions (Ref. 17).

In addition to their effect upon fatigue behavior of rail, inclusions appear also to influence the dry wear process. Figure 12, taken from the work of Fegredo et al. (18) shows a linear relationship of dry wear rate

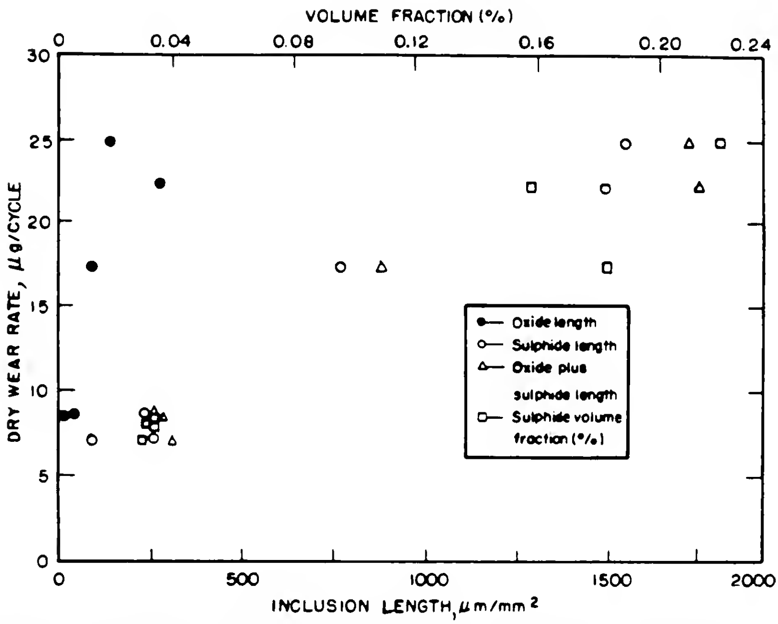
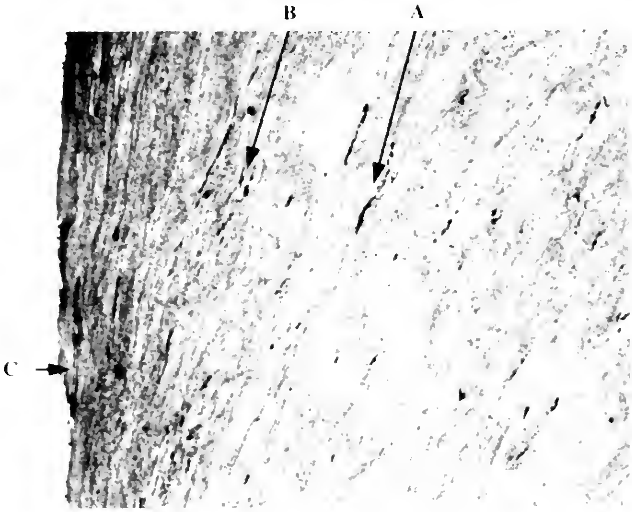


Figure 12. Laboratory Dry Wear Rate of Rail Steel as a Function of Inclusion Parameters (Ref. 18).

with inclusion content. Manganese sulphide inclusions have been shown (19, 20) to be associated with deformation cracking which appears to be linked to the dry wear process (Figure 13).



100X

Feature A 200X

Figure 13. Inclusions/Cracks Appearing in a Transverse at the Gage Corner of a Chessie System Rail (Ref. 20).

A 4:1 reduction in wear rate (approximately) results from a 5:1 reduction in inclusion content. Rail steels produced 10-20 years ago probably were in the 0.15-0.30% range for inclusion content. But rail steels produced today both in North America and abroad using clean steel practices probably have inclusion contents more nearly at the low end of the plot. Thus, it is not clear whether further improvements in cleanliness, particularly reductions in the amounts of manganese sulphides, will yield much improvement in wear resistance without appreciable increase in cost.

Through the years, improvements in steel making practices have led to lower sulphur and oxygen contents in rail steel. Most recently, the need for stronger 'standard' carbon rail steel has led to an increase in the level of manganese accompanying the reduction in sulphur content. We need to be reminded that Heller et al. (21) noted in 1972 that reduced sulphur and increased manganese contents increase the susceptibility to shatter cracking in rail steels (Figures 14 and 15). When hydrogen is removed from the molten steel and is kept out of the steel throughout the remainder of the rail manufacturing process, low sulphur and high manganese contents need not lead to a hydrogen problem. But, if the hydrogen content is high in the melt, perhaps over five ppm, then controlled cooling must function exactly properly in order to bring the hydrogen content down to a satisfactory level. There have been some cases in the last few years where controlled cooling has not performed as expected.

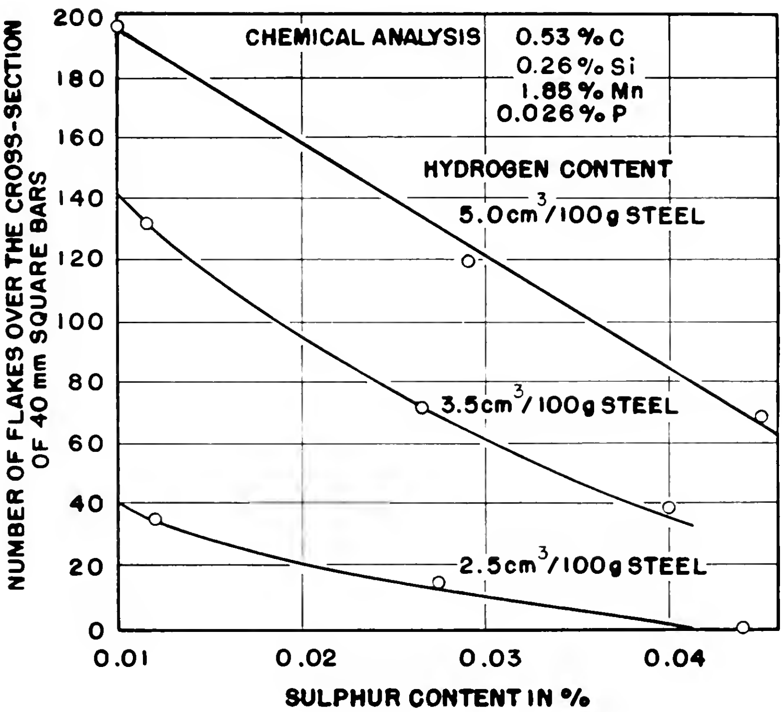


Figure 14. Effect of Sulphur Level and Hydrogen Level on Flake Occurrence (Ref. 21).

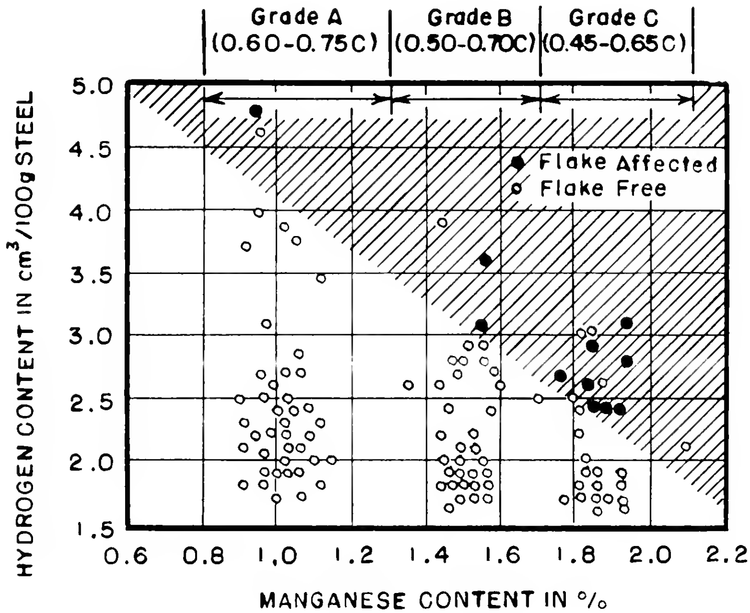


Figure 15. Effect of Manganese Level on the Hydrogen Level Associated with Flake Formulation (Ref. 21).

Up to this point, the discussion has focused on metallurgical considerations. But how well a particular metallurgy will perform in service depends to a greater extent than is imagined at times on the wheel/rail contact conditions. The contact conditions are strongly influenced by the wheel and rail profile. Thus the profile has great importance by influencing:

a. truck lateral stability on tangent track, i.e. hunting,
b. curve negotiation through angle of attack and forces, and
c. level and depth variation of contact stress as a function of contact zone radius of curvature.

Topics (b) and (c) are especially important because together they control wear, plastic deformation, and fatigue (in the rail head). Indeed, the concentration of high wheel loads in a narrow band on regions of small radius of curvature has caused significant contact fatigue damage in rails of great strength and wear resistance. Figure 16 shows such damage which has developed early in the life of a premium rail under well lubricated conditions.

One of the perhaps previously unappreciated problems with high premium rail is its resistance to changing contact profile shape especially under well lubricated conditions. If, as a consequence of track gage and wheel contour, virtually all the wheel load is forced onto a small radius portion of the profile i.e. the corner radius, the expected fatigue life will be shortened immensely. This is illustrated in Figure 17. Here the AAR/TSC three dimensional fatigue program, PHOENIX, has been used to calculate the first percentile life of a premium rail expected under FAST unit train conditions for different crown radii under pure Hertzian contact conditions. As the radius of curvature upon which the load is concentrated decreases toward the typical rail corner radius, the expected fatigue life drops rapidly to 15-20 MGT. And

Figure 16. Gage Corner Spalling of a Head Hardened Rail in Well Lubricated Track (Courtesy of A. Merritt, Seaboard System).

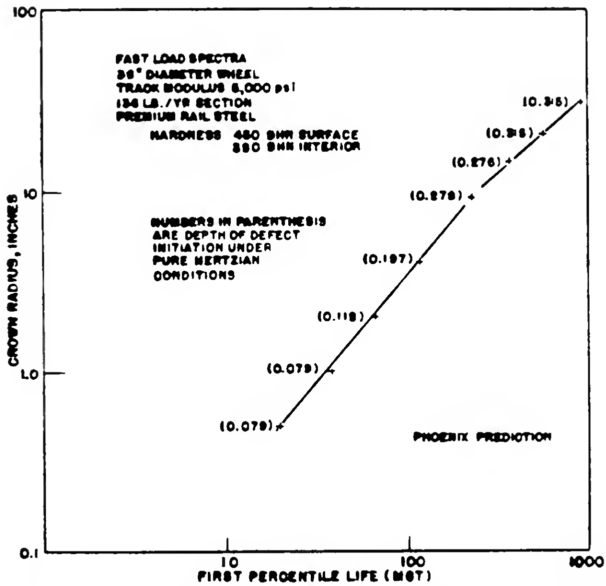


Figure 17. PHOENIX Prediction of First Percentile Rail Fatigue Life as a Function of Crown Radius.

the position at which fatigue failure would initiate rapidly approaches the surface. Were appreciable surface tractions present, the life would be shorter and the depth of damage would be even less than that expected for Hertzian conditions.

Where the rail is softer, especially where the wheel/rail interface is dry, wear and plastic deformation will quickly reconfigure the rail profile into a shape which distributes the wheel load over a greater contact area. One might then expect that worn rail profiles offer a clue as to a relatively stable configuration which will distribute the wheel load most charitably. The radius variations of a stable FAST curve worn profile (high rail) and the average worn rail profile reported by Blader (22) are shown in Figure 18. Both are characterized by a large contact radius (even greater than the as-manufactured radius) at the center of the rail head. The contact radius diminishes gradually until the smallest radius occurs right on the gage

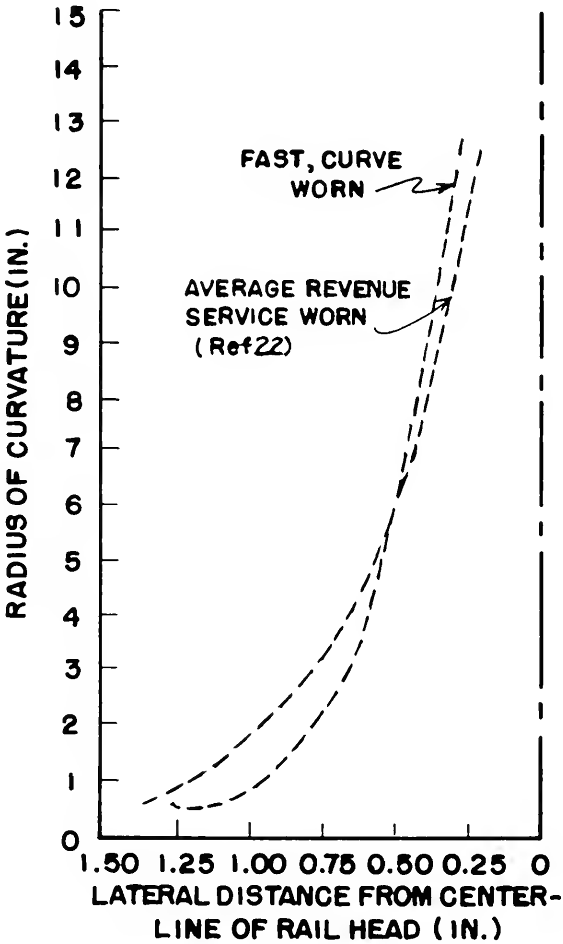


Figure 18. Radii of Curvature of Worn Rail.

corner. Figure 19 illustrates how far the as-manufactured 136 lb/yd profile is from the worn profile configurations. A more reasonable match with the worn profiles can be had by maintaining some large crown radius at the center of the rail head and then blending the surface configuration to the side of the rail head using a Grodzinski spiral. Such a configuration with a 14" center crown radius is shown in Figure 20. Figure 21 illustrates the manner in which a Grodzinski spiral is constructed.

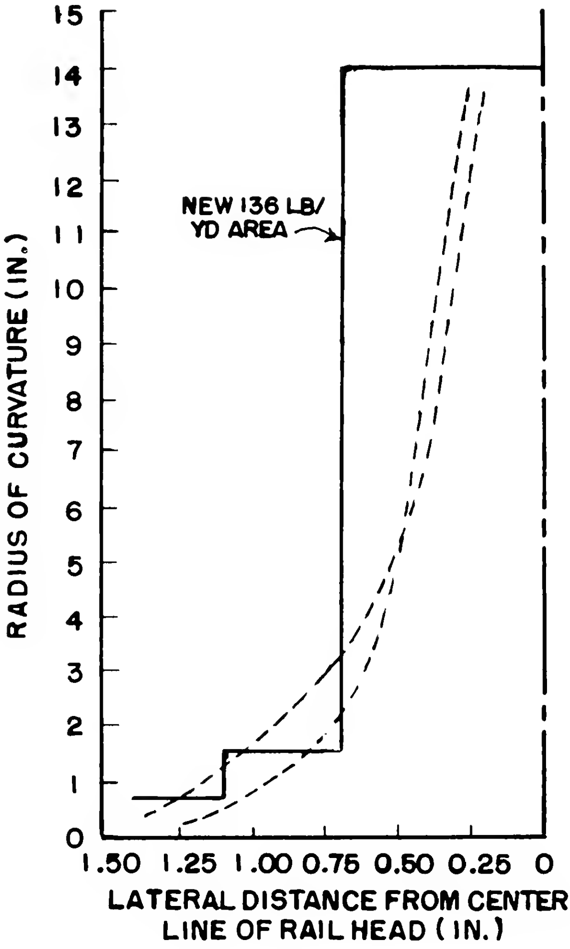


Figure 19. Comparison of Radii of Curvature of Worn Rail with New AREA 136 lb/yd (Nominal Design Profile).

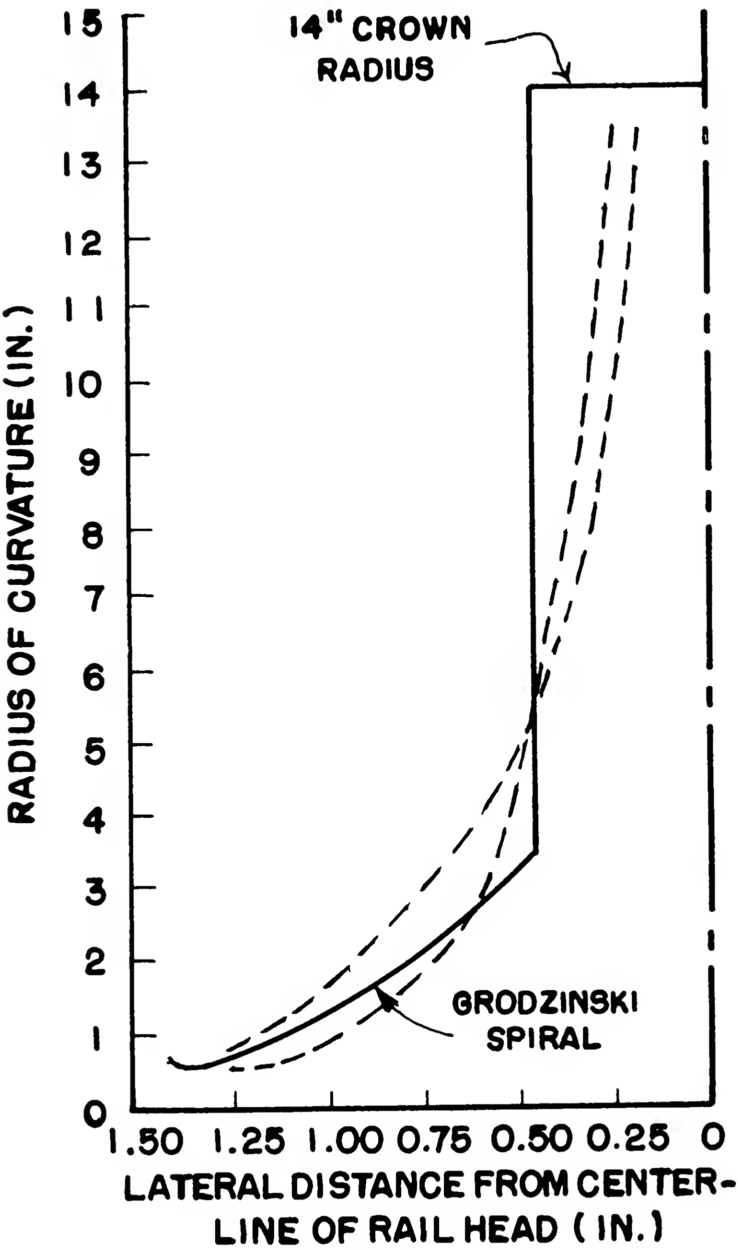


Figure 20. Comparison of Radii of Curvature of Worn Rail with Grodzinski Spiral/14″ Crown Radius Design.

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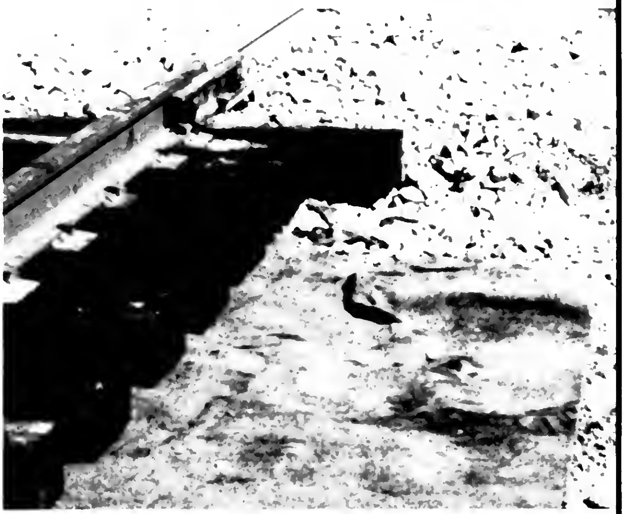

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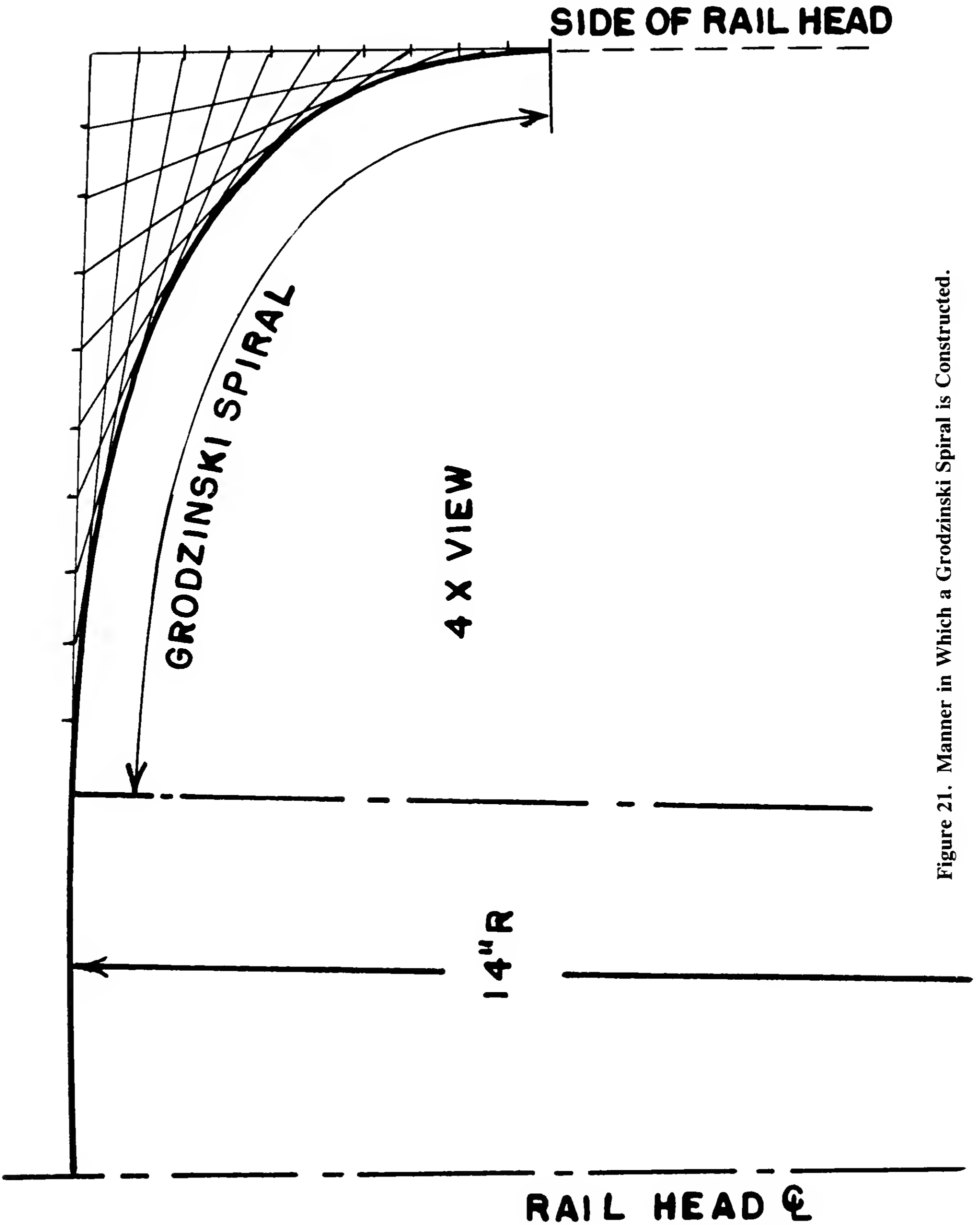

Figure 21. Manner in Which a Grodzinski Spiral is Constructed.

Before leaving the topic of rail profile, a few words need to be said about the value of having a worn gage face. Normally, when new rail is installed in a curve, the action of wheel flanges, especially under unlubricated conditions will quickly create a worn gage face. Typically, the average slope of that gage face is about 3:1. The Elkins Gostling (23) curving model has been used to calculate how flanging upon a gage face will influence the force distribution into the rail. The results of the calculations are presented in Figure 22.

With the worn FAST wheel profile, when there is no worn gage face (new 136 lb/yd AREA section), the entire wheel load is carried on a single 'point,' i.e., area of contact, which is at the gage corner of the rail. However, when there is a gage face and the flange bears upon it, the loads are partitioned between the gage face and the tread. When the gage face is unlubricated, in the case calculated (6° curvature, 2″ unbalance), the gage face carries more than one half of the vertical load and the tread is partially unloaded. Of course, the penalty for this is high gage face wear and high curving train resistance.

If the gage face is lubricated (friction coefficient = 0.1), the tread is still partially unloaded by the partitioning of vertical load to the gage face. But the degree to which this occurs is less than in the unlubricated case. With effective lubrication on the gage face, gage face wear will be reduced immensely (24) and train resistance will be brought down to manageable levels (25). Thus, it appears that flanging upon a well developed gage face under lubricated conditions can be beneficial to the distribution of loads into the rail without wear or train resistance penalties. But one caveat must be stated. In the long run, suppression of wear by lubrication will prolong rail life enough so that internal fatigue (i.e., shell/TD formation) eventually will become the cause of rail replacement (24). The degree of benefit (to rail life) one achieves from lubrication will depend upon curvature, wheel load, metallurgical character of the rail, and the extent to which *natural* and/or *artificial* wear (i.e., grinding) are caused to occur.

SUMMARY

The problem of softened, batter-prone welds of heat treated rails has tended to limit the serviceability of otherwise excellent performing rail. However, methods have been developed for the continuous heat treatment of long CWR strings thereby eliminating the soft-weld problem. A simpler method which offers the same benefit for weldments is air quenching in the weld plant. Heat treatment of the entire rail section enhances resistance to rapid weld crack propagation, a problem which has been associated with some roller straightened CrV rail. That problem has *not* been observed in any other rail metallurgies including other alloys even though these other rails are roller straightened as well. Micro alloying to produce a finer pearlitic structure and the use of low carbon bainitic steels offer potential for improved rail serviceability.

The benefits of using rails having lower oxide and sulfide inclusion contents has come under close scrutiny. Rail steel cleanliness has improved with the introduction of better steel making practices. But a question has remained, to what degree further improvements in cleanliness can be beneficial to wear and fatigue resistance. A consequence of the reduction in sulphur is the need to pay particular attention to hydrogen content.

The application of lubrication to high strength head hardened rail steels has, in several instances, reduced wear to the extent that contact fatigue has become a problem. This has occurred under circumstances where wheel/rail contact has been restricted to a narrow zone on the small corner radius of the rail. Worn rail profiles, especially those having a distinct worn gage face (high rail), distribute the contact forces more charitably. A Godzinski spiral provides a good simulation of the worn profile on the ball of the rail. Potentially, changes in the rail (and wheel) profile can offer the possibility of improved rail performance.

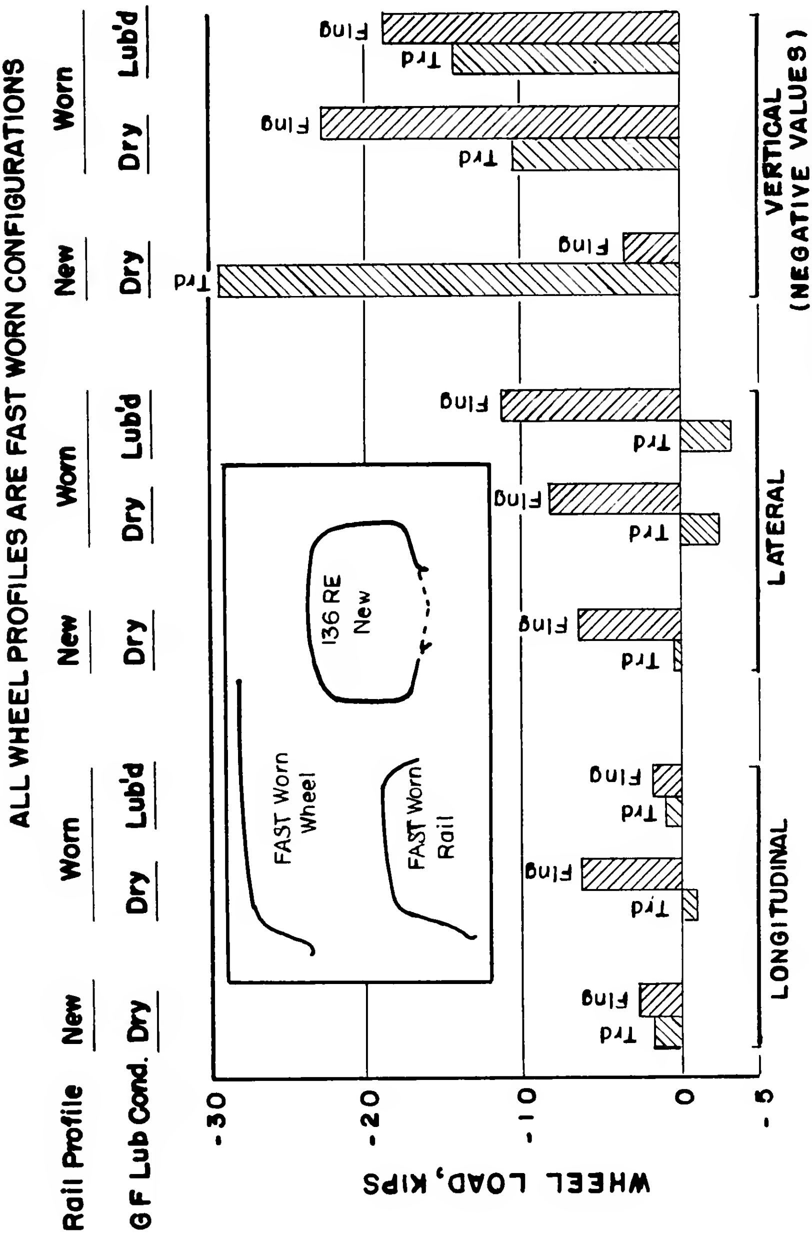

Figure 22. Effect of Flange Contact and Lubrication State upon Wheel Forces on High Rail of Curve.

ACKNOWLEDGMENT

The authors are grateful to Peter Klauser of the Association of American Railroads for developing the calculation routine which permits the determination of crown radius from x, y coordinate pairs, and for making the calculations of radius which appear in Figures 18, 19, and 20. The efforts of Robert Z. Lin of the Association of American Railroads in making the curving model calculations are appreciated.

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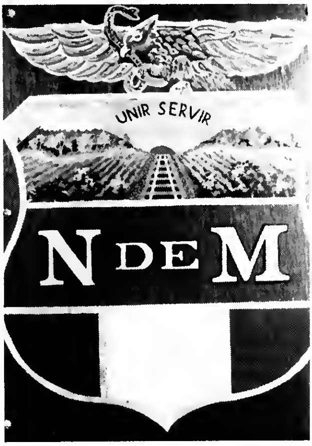
Table I. Comparative Tensile Properties of Conventional Pearlitic and Carbide-Free Bainitic Rail Steel

	Pearlitic	Bainitic
0.2% YS (ksi)	64	99
UTS (ksi)	121	155
Hardness (BHN)	260	340
% Elongation	22	16
% Reduction of Area	30	25

Railway Track and Bridge Work in Mexico

C. Zamarripa M.* and J. S. Vargas Z.**

Presentation to 1986
AREA Technical Conference
Chicago, Illinois, March 25, 1986



National Railways
of Mexico Symbol

I appreciate the opportunity to talk to you, on behalf of the Mexican railroaders. Particularly, I would like to transmit to you the affectionate greetings of our General Director, Mr. Eduardo A. Cota, and of our Vice President of the Track and Structures area, Mr. Romualdo Ruiz Castro, who was distinguished as Regional Director of A.R.E.A., and whom we come representing.

Our participation is modest but none the less important. It is our wish to let you know what we are actually doing in the railways matter in our country. Since your last visit in October 1984, we have clearly stated the compromise we have in modernizing our railways system in order to deal with the demand, each time higher, for rail service.

It should be mentioned that the Mexican Railways System has 19,907 km. of main track, which includes 12, 918 km. of spiked traditional or classic track, 2,240 km. of track with welded rail on timber ties and 3,089 km. of elastic track, with welded rail on concrete ties. Attention is required to the low structural capacity with respect to the loads that have increased in volume and axle weight; besides inadequate maintenance on some lines due to the lack of financial resources and because there is no justification for major investment due to reduced freight traffic.

Recently after an exhaustive diagnosis of the physical conditions of the track, 1780 km. of critical stretches were established as requiring drastic intervention; 1318 km. need intensive maintenance because it was deferred, besides renewing the integral track (500 km. per year) with new 115 pounds per yard rail, and starting to lay a heavier rail of 136 lbs/yd, between Achotal and Medias Aguas in the southeast zone. There will be an investment of about 50 million dollars per year, in order to have in a 10 year period of reliable track for the traffic demand. This substantial effort is being done independently of what is being done in bridges and culverts, where the programs include the rehabilitation, reinforcing and construction of those of low capacity, obsolete design or those with a high degree of corrosion.

* Chief Engineer, Track and Structures Department, National Railways of Mexico
** Chief Engineer, Track Machinery Department, National Railways of Mexico

To accomplish this year's program, we are working in 14 fronts of new rail relay, semimechanized and are obtaining about 50 km. monthly. Also we have 8 fronts of second hand rail relaying to which we add the rehabilitation of the main yards at Valle de Mexico, Monterrey, Guadalajara, Veracruz, Irapuato, Nuevo Laredo and Matamoros, main cities in the Country.

The modernization mentioned includes the total mechanization of the track renewal works, because the production obtained is less than required.

Current Modernization of Track Works At Mexican Railways

On several previous occasions in this same forum, we have presented ambitious projects and realizations of the Mexican Government, through the Ministry of Communications and Transportation with a view to the future Mexican Railways System. A good example of this was, the double electrified track between Mexico City and Queretaro, still under construction, which was visited by A.R.E.A. members during the regional meeting held in Mexico in 1984. The future system will greatly increase the railway's usefulness in our country.

Meanwhile, what are we doing to supply a good, safe and reliable rail transportation service? As it is known, the actual Mexican Railway System was projected, designed, and built for the needs, conditions, and with the means available one hundred years ago; of course under specifications, with materials and methods that were actually used the past century, and under the criteria of the minimum initial cost.

The result of this now is, we are facing the problems of the steep grades, sharp curvature, and remaining old materials. The first two; grades and curvature, are being modified mainly by the Federal Government as I mentioned at the beginning, and the railway companies themselves are taking care of the rehabilitation, renewal, and modernization of all the old facilities and track problems increased and

Installation of Concrete Ties

aggravated by the destruction held during the Mexican revolutionary war between 1911 and 1920, and by the abandonment of the routine maintenance works until World War II. In the long term only two main lines of the National Railways of Mexico were rehabilitated between 1940 and 1946: line "B" between Mexico City and Nuevo Laredo at the Texas border; and the "K" line at the Panamericano Division between Ixtepec and Suchiate at the border with Guatemala. Both were for military strategical purposes during the second war already mentioned.

Several attempts have been made since 1950 to rehabilitate the National Railways of Mexico. It was not until this administration, that the Government started strongly supporting and upholding N de M Railways with the firm purpose of modernizing and improving the actual system.

In this presentation I will limit myself to talk about track and structures area.

The 1982-1988 schedule looks forward to reach the following goals, after the work of the registration car.

2,548 km. (1,584 mi.) of integral track renewal, which includes the total replacement of old rails by new, increasing the weight to 115 pounds per yard rail, old timber ties by new concrete ties in about 86.5%, and the rest by new timber ties, old switches and frogs by new ones of the new weight naturally, and all the old fastenings by new.

1,532 km. (952 mi.) of track rehabilitated with the old second hand rail with it's ties and fastenings still in good condition.

14,187 km. (8,817 mi.) of track ballasted and surfaced.

Enlargement and modernization of the freight yards in Guadalajara, Monterrey, Valle de Mexico, Veracruz, and Tierra Blanca, which are among the main cities in the Country.

At the same time we have scheduled 2,325 km. of embankment reinforcement, which is done partially by contract and partially by administration.

As it is easy to understand, the start and execution of the program has been seriously affected by the economic crisis that this Country is suffering. Consequently, starting in 1983, we have been able to accomplish the following items:

696 km. (433 mi.) of integral track renewal, all with new materials.

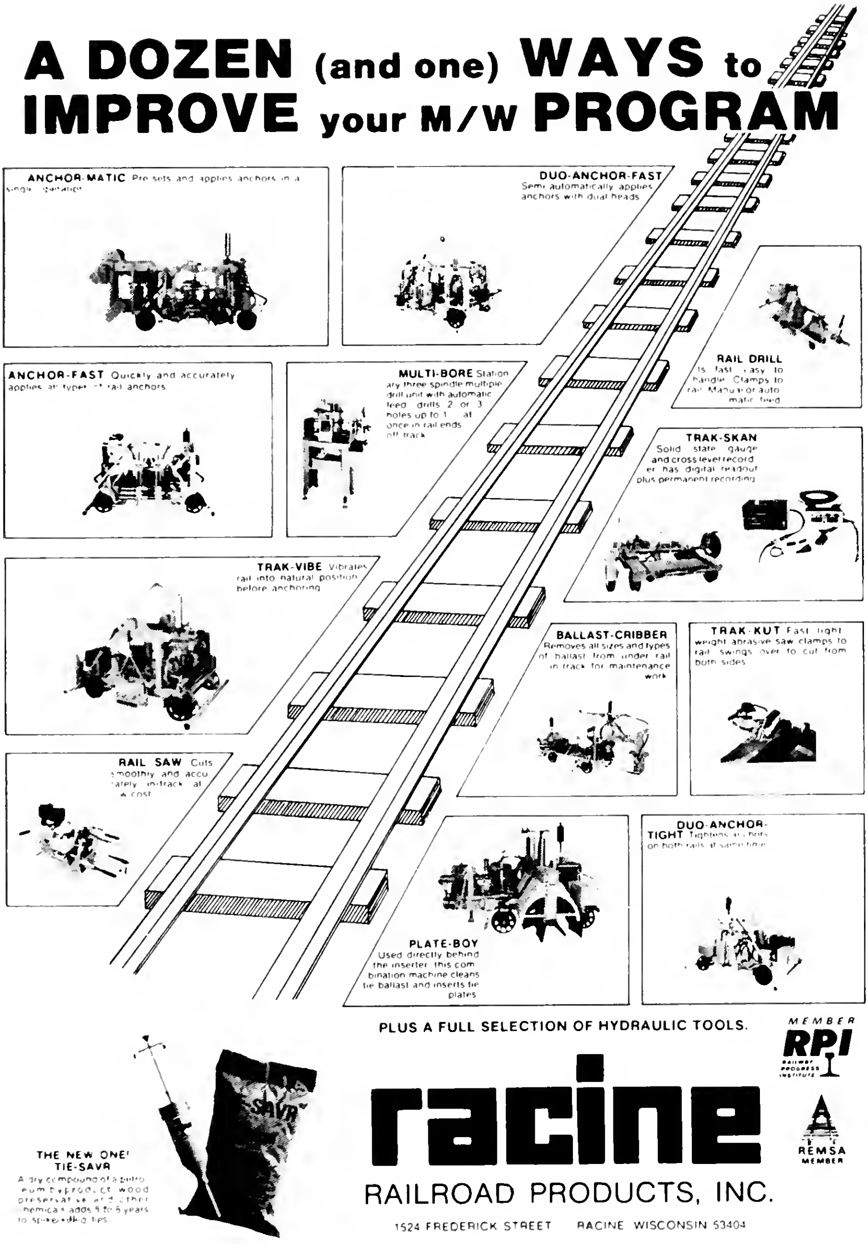
559 km. (347 mi.) of track rehabilitated, with second hand materials.

4,488 km. (2,789 mi.) of track ballasted and surfaced.

In order to accomplish the program scheduled, we have realized that it is absolutely necessary to mechanize to the highest degree possible for the different operations involved in the work listed. Consequently, we have also scheduled for the coming years, the purchase of a number of machines, which will allow us to reach the goals that we have established.

Starting next month we expect to receive this year the following maintenance of way equipment:

20 Tamping leveling-lining machines, from which 5 are also for switches.
10 Independent track liners.
10 Ballast regulators.
10 Tie exchangers.
2 Spreader ditchers.
1 Ballast cribber-cleanser.
2 Cranes convertible to pile drivers, rail wheel mounted.
5 Track cranes for 45,000 lbs. max. cap.
2 Track cranes rubber mounted.
1 Mobile welding plant.
30 Track fastening tighteners.
4 Hydraulic jacks.
10 Mechanical bolt tighteners.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TRAK-VIBE Vibrates rail into natural position before anchoring
BALLAST-CRIBBER Removes all sizes and types of ballast from under rail in track for maintenance work
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New Mechanized Track Equipment on N de M

8 Adzing machines.
2 400 amp electric welders.
5 Mechanical anchor fastener-tighteners.
29 Inspection motor cars.
50 Section motor cars.
69 Gang motor cars.
And a group of mechanical tools for miscellaneous works.

This total group will be increased by the units to be purchased in '87-'88, which include the purchase of at least two renewal trains type P 811, P-90 or similar.

Up to date, we have working 14 fronts of integral track renewals in which we are substituting all the track superstructure with new material. We have also 8 working fronts with second hand material. Fourteen fronts of reballasting and surfacing, and 4 fronts of spot tamping.

Due to the lack of equipment, we don't have all the fronts completely mechanized, consequently we have been applying a mixed method using a minimum of machinery and taking advantage of the hand labor available.

The procedure used involves the following steps:

Unloading and distribution of the long welded rail in strings of 274 m. (897 ft.) (23 x 39′) on the shoulders of the embankment.

Unloading and distribution of the new concrete or timber ties on one side of the track, more or less lined and squared with respect to the track axis.

With a track crane, we dismantle the track pulling out a complete panel, one rail 39′ long.

With a ballast grader or using a sled built by us, smooth off the track bed and lay and distribute new ties by hand.

Distribution and installation of the new fastenings and rubber plates.


EGGS
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Tightening of the new track structure with mechanical tools.

Unloading and distributing new ballast; surfacing of the track stretch by means of one tamping leveling lining machine, one ballast regulator and one ballast compactor.

A variation of the procedure to replace the track superstructure is as follows:
Dismantling of the used rails using a track crane and laying the new rails with the same crane.

Leaving gage ties, we pull out the old ties, with tie inserters or with a tic exchanger.

Clean or smooth the cribs or track bed by means of a ballast grader.

Insert the new ties, with two tie inserters or one tie exchanger, and the rest of the operation is as previously described.

It is necessary to mention that on N de M, the Track Machinery Department was created and started to work on January 2, 1975.

In order to be capable of maintaining the important group of machinery that is about to arrive, we already have under construction the first new shop in the system to take care of all the major repairs of the maintenance of way equipment. This facility will have 4395 m^2. (47,307 ft^2.) of covered area and is designed for the repair of all the group components of the machines; diesel engine, transmission and power trains, hydraulic, electric and pneumatic systems; gasoline engines of the motor cars; body and frame or chassis, and final paint.

It also has 2 traveling cranes, 15 and 10 ton capacity each with the clearance necessary to overhaul the various types of cranes that we own.

At the same time we are reorganizing the Track Machinery Department, dividing the system into five regions. We are working over the project of the adaptation of two existing buildings, one in Monterrey and the other in Aguascalientes, to have another two regional shops.

Taking into account the near future merger of N de M with the other three exisiting railways in the Mexican System, we have decided to locate the two remaining shops in Coatzacoalcos in the southeast, and in the north in Chihuahua.

Logically, in order to have the capacity to face this big challenge, we have not forgotten the important line referred to the personnels' training.

In the past, this training was given to the track people, from foreman to principal or regional engineers by the Railroad's Training Institute.

The administration is giving attention to training, increasing the courses, the instructors and the people to receive them, trying to reach the largest amount of personnel possible.

For the maintenance of way equipment personnel, the training obtained in the past was very poor, due mainly to the lack of qualified instructors, didactic material, facilities and budget.

In the last 13 years we have had the opportunity to send about 32 men to the training schools of several manufacturers of equipment.

It was in 1985, that this administration, for the first time approved to pay the training courses of 32 laborers at a private school in order to raise them to mechanics.

For this year the budget has been increased and at the same time, provisions are being taken in order to supply this training at our own Training Institute in the shortest term possible. This year also, for training our people, we will take advantage of the support and aid offered by our suppliers at their facilities.

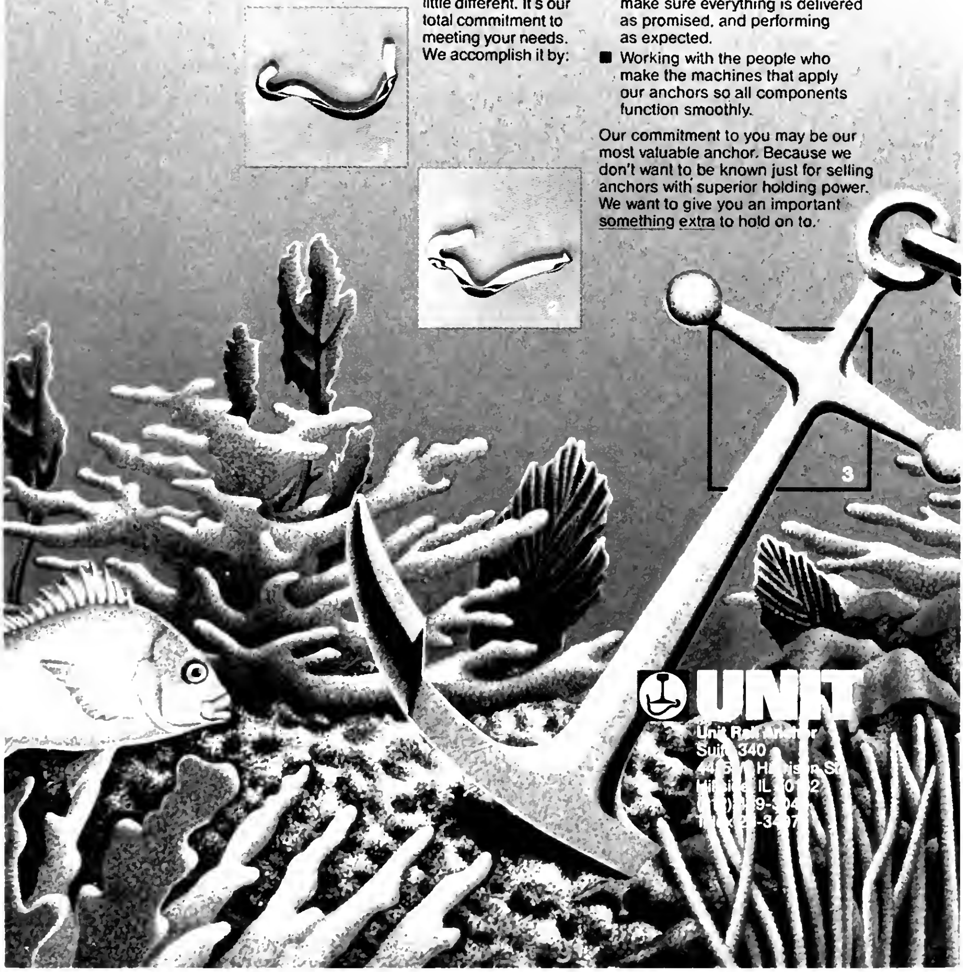
You already know about two of our anchors.

Our drive-on and spring anchors are famous for delivering outstanding holding power—and laboratory comparison tests have proven their superiority time and time again.

The third anchor that Unit offers you is a little different. It's our total commitment to meeting your needs. We accomplish it by:

- Constantly improving our manufacturing efficiency to control the cost of bringing our product to you
- Planning our manufacturing and inventories to your planned purchases. We're your partners in the purchasing and material control process, not merely a supplier
- Giving you the assurance of the best on-time delivery record in the business.
- Providing you with complete technical support. This includes working with your rail gangs to make sure everything is delivered as promised, and performing as expected.
- Working with the people who make the machines that apply our anchors so all components function smoothly.

Our commitment to you may be our most valuable anchor. Because we don't want to be known just for selling anchors with superior holding power. We want to give you an important something extra to hold on to.



Let us change now and talk about the bridge problem at Nacionales de Mexico.

This problem has its origin in the age and in the provisional construction of them, because they mostly were built late in the past century or in the first decade of the present century.

On the Mexican Railway System we have 14,100 bridges including more than 6,000 which are the weakest points of our maintracks due to their low load capacity or to their physical truss deterioration. Still, at the 60's decade the traffic interruptions in some mainlines near to the Gulf Coast and the Pacific shore were due to track washes and to the bad physical conditions of the trusses.

Since 1973, we are working under schedule to solve the problem of the bridges.

We have established the following goals:

1. Guaranty the safety of the train traffic.
2. Maintain the traffic fluidity.
3. Operate without restriction, load equipment of high capacity. For instance, diesel electric locomotives from 3000 to 3600 H.P. and freight cars up to 100 ton load capacity.

New bridge on N de M for 263,000 lb traffic

To obtain these objectives, we have set several actions to follow which in order of priority are the following:

a). Bridge reinforcements will be necessary in those lines of low or high traffic density, in which the truss deterioration puts in danger the train traffic.
b). Load capacity increases in those lines of low traffic density by reinforcing or rebuilding the bridges.
c). Replacement of timber bridges by concrete or metallic structures in those track stretches that because of their location are in danger of fire.

Bridge Replacement and Strengthening on N de M

To date, we have rebuilt more than 2300 bridges and we have reinforced more than 1500 with which we have avoided the existing danger in many points and practically the capacity of several main lines has been increased to a load Cooper E 72 capacity. Such lines are: Mexico City - Nuevo Laredo, Monterrey - Matamoros, Saltillo - Piedras Negras, Mexico City - Guadalajara, Mexico City - Jalapa - Veracruz, Veracruz - Tierra Blanca, Cordoba - Medias Aguas, and Medias Aguas - Coatzacoalcos.

The results obtained which really represent a modernization of the structures have been reached by two basic procedures:

Reinforcement and replacement.

To increase the load capacity of each bridge, first has been studied the reinforcement possibility, and only when this is not possible because of the low load capacity of the existing truss or because of its deterioration degree, we decide for the replacement, following the A.R.E.A. standards. There has been very important metallic truss reinforcements that have been made which have changed the old fashioned shape to a modern and functional one.

In cases of through pass trusses, the reinforcement has been done by adding plates and profiles to the sections.

This has been applied at Papaloapan, Tancochapa, Blanco and Obispo Rivers in Veracruz, in the southeast, and Armeria River in Colima in the southwest.

On deck trusses the reinforcement has been done by adding a central truss and a concrete slab to hold the track ballast. We have done this in the bridges between Atenquique and Colima in the southwest.

In such cases where we replace the short span trusses, we have done more than 1300 replacements with prestressed concrete beams box section, and trestles of prestressed concrete piles type "A," or three piles.

Correction to Paper

"A Method for Determing the Track Modulus Using a Locomotive or Car on Multi-Axle Trucks" by Arnold D. Kerr, Proc. AREA, Vol. 84, Bulletin 692, 1983.

In Fig. 5 and Fig. 6 the descriptions 100RE and 140RE should be interchanged, in order to conform with the computer printout of Table 1.

DIRECTORY OF CONSULTING ENGINEERS

AREA

DECEMBER 1986

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50 F St., N.W.
WASHINGTON, D.C. 20001
U.S.A.

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Cover photo: Burlington Northern mainline in Marias Pass, Montana, as viewed from rear of B.N. inspection car. August 1, 1985

Rear cover photo: Construction of new railway bridge for Chicago and North Western Coal Line near Torrington, Wyoming. May, 1984.

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Excerpts From 1986 Annual Report of A.R.E.A. Committee 1 — Roadway and Ballast

H. C. Archdeacon, Chairman

Subcommittee 1. Roadbed.

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

Assigned in 1986. Anticipate proposed text for information report will be presented to vote at the October meeting.

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

Assigned in 1986. Anticipate authority will be sought at the October meeting to circulate a letter ballot.

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

Assigned in 1986. This assignment will probably require 2 more years to complete. There will be no interim report this year. This assignment was proposed because of concerns of some members faced with proposals from consultants for the use of such units. The concern is primarily that the consultants' experience is usually not based on railroad loading, and the reviewing railroad engineers need some guidance from the Manual.

Subcommittee 2. Ballast.

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

This assignment has been under development for at least three years. It is anticipated that a plan of study as recommended by the subcommittee will be presented for committee approval at the October meeting. If approved, the assignment can be terminated.

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

This assignment consists of the implementation of assignment 2(a). It is anticipated that it will require several years to complete.

*(c) Furnish input and act as a steering committee for the AAR ballast research program. Review and monitor the AAR program and the interpretation of all ballast test data prior to dissemination.

*(d) Report on results of AAR and other appropriate ballast research programs. Utilize suitable elements as part of AREA plan of study.

These assignments were rewritten in 1986. By their nature it is anticipated that they will be continuing assignments.

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

This assignment has been under development for at least three years. Most of the work has been completed and extensive Manual revisions have been adopted. There is some work not yet completed. Present plans are to finalize it in 1987.

Subcommittee 3. Natural waterways.

*(a) Develop recommendations for the gradation, sizing, composition and placement of rip-rap for the various applications presently described in the Manual.

Assigned in 1986. The subcommittee has determined that there is not general support for modifications to the current Manual text. Anticipate that a recommendation will be made at the October meeting to drop this assignment.

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

Assigned in 1986. The subcommittee is engaged in a study of the literature available on this subject. Their goal is to complete this assignment in 1987. Their final recommendations may be to adopt a bibliography to acompany the present Manual text.

Subcommittee 4. Culverts and drainage pipe.

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

Assigned in 1986. No interim report to be made. The assignment is progressing satisfactorily. The subcommittee plans to ask approval to issue a letter ballot at the spring meeting in 1987. The inclusion of this material in the Manual will aid the railroad engineer in making decisions on culvert sizing.

(b) Develop use of plastic culvert pipe under railroad loading.

A final report has been submitted on this assignment.

Subcommittee 5. Pipelines.

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

(b) Study use of plastic carrier pipes.

These assignments were adopted because of current practices within the pipeline industry and are considered to be highly relevant. The help of Board members in getting their pipeline specialists on Committee 1 and actively working would be appreciated.

Subcommittee 6. Fences.

(a) Revise in decimal format.

The work on this assignment has progressed to the point that a letter ballot is now being circulated. If approved, we will propose a new assignment to expand this part of the Manual by including recommendations for security fencing.

Subcommittee 7. Signs.

There is no actively functioning subcommittee for this part of the Manual, and no proposed assignments for 1987.

Subcommittee 8. Tunnels.

There is no actively functioning subcommittee for this part of the Manual at present. It is proposed to reactivate this subcommittee in 1987 with two new assignments. One assignment would be to review and update the present Manual part on tunnels. The other assignment would be to develop an informational report on the design and construction of the Canadian Pacific's new tunnel in the Rockies. It is anticipated that both of these would be two year assignments.

Subcommittee 9. Vegetation control.

*(a) Revise the vegetation control glossary.

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

(a) and (b) Both of these assignments were new in 1986. Work is progressing satisfactorily on both of them. It is hoped that they can be completed in 1987. Assignment (a) is an updating of present Manual material. Assignment (b) is intended to give the railroad engineer who is developing or executing vegetation control programs additional guidance.

Subcommittee 10. Geosynthetics.

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

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

Both of these assignments were new in 1986. Work is progressing satisfactorily on both of them. It is anticipated that another year's work will be required to complete them. Because of time constraints imposed by the letter ballot system, they will probably carry over into 1988. Both of these assignments are intended to broaden the scope of the new Manual section on geosynthetics established last year. No additional help is required. No changes in these assignments are recommended.

Excerpts From 1986 Annual Report of A.R.E.A. Committee 2 — Track Measuring Systems

M. D. Roney, Chairman

Subcommittee 1 Rail Planimetry

Assignment: Prepare a glossary of standard terms related to the evaluation of rail deterioration.

Assigned: October, 1984

Progress to Date: Complete. Glossary was approved at January meeting and will be submitted for 1987 manual chapter.

Benefits of Assignment: Standard terminology for rail surface defects will assist in sharing of information on shelling and corrugation problems and enables writing of specifications for rail surface analyzer vehicles.

New Assignment: The Committee wishes to formally replace the above assignment with one that reads:

"Investigate the characteristics of corrugations prevalent on North American railways to establish specifications for their measurement by automated means".

This assignment has been active since October, 1985. Corrugation data has been collected on the CN, Conrail, CP, Seaboard and NS and has been analyzed to establish relationships between depth and wavelength in unit train and mixed freight territories and on concrete vs. wood tie track.

Results to date have shown interesting similarities between corrugations on different railways, but marked differences between wood and concrete. In addition to improving our understanding of corrugations these results will enable measurement specifications to be drawn that will ensure that critical corrugations are accurately measured.

Subcommittee 2 Track Surveying

Assignment: Establish the need for track survey data and the requirement of each data element to be updated.

Assigned: October 1984.

Progress to Date: The Subcommittee has completed a survey of data base information compiled by the various railways. The next task will be to evaluate how data should be collected, and specifically what data can be collected automatically.

Examples would be line clearance, switch locations, gradient, curvature, rail condition and track geometry condition.

Benefits of Assignment: The assignment will lead to education of the rail community on the opportunity and procedures for using automated measurements to update data bases.

Comments: This assignment will lead to specifications for the use of geometry or clearance cars to update track data bases.

Subcommittee 3 New Technologies

Assignment: Evaluate the need and opportunity for new track measurement technologies.

Assigned: October 1984

Progress to Date: A questionnaire intended to evaluate priorities for new types of track measurements was rewritten to gauge the possible economic benefits of 13 new measurement systems that are considered to be feasible with current technology. It has been submitted for responses from the Committee members.

Benefits of Assignment: The results will establish proposed research priorities for new track inspection tools and will encourage new technology.

Subcommittee 4 Track Geometry Car Development

Chairman: R. Harbuck

Assignment: Prepare a glossary of standard definitions of track geometry terms.

Assigned: October 1984

Progress to Date: Glossary has been prepared and is intended to be submitted for the 1987 AREA Manual.

An inventory of types and characteristics of geometry cars used by the industry has also been completed.

Benefits of Assignment: Glossary will ease communication of track geometry issues and enable geometry car standards to be written.

New Assignment: The Subcommittee is now prepared to define a new assignment to propose standards for track geometry cars.

Subcommittee 5 Track Geometry Analysis

Assignment: Survey data processing techniques used on different railways and recommend a standardized track rating technique.

Progress to Date: The Subcommittee has developed a method for describing each railway's Track Quality Index (TQI) in terms that could be related to another railway's TQI.

Future work will develop the pros and cons of different track rating techniques.

Comment: By the very subjective nature of track quality rating, this task has generated much philosophical discussion. It is expected that the outcome of this work would be a paper on the state of the art in rating track. Hard recommendations would follow much later.

Benefits of Assignment: Sharing of information on factors influencing track quality and their quantification in standard terms.

Subcommittee 6 Rail Flaw Detection

Assignment: Develop a recommended practice describing minimum acceptable flaw detection capabilities in terms of flaw types and sizes.

Assigned: March 1986

Progress to Date: The Subcommittee has produced a draft statement of performance requirements for rail flaw detection systems that is currently under review by the Committee.

Benefits of Assignment: This document would provide a specification for detection equipment that provides adequate protection, assuming inspection intervals as proposed by Committee 4, and against which detection equipment performance can be compared.

New Assignment: Future work will develop the means by which adherence to this specification can be measured.

Comments: This Subcommittee is active and enthusiastic, but is too small to produce industry standards on its own. Airing of the proposals in front of the Committee on Rail Testing is one possibility, however this forum is thought to be cautious to AREA's involvement. It is recommended that the resources of CORT be used for feedback in the short term. A more permanent solution would be an appeal to Chief Engineer for representatives in the rail flaw testing area.

Special Assignment A Crosslevel Index Comparisons

Objective: To gain experience in using the FRA Crosslevel Index in comparison to the existing geometry measures.

Status: Complete

Result: CL1 and CL1M found to correlate with existing measures. CL1M offers additional information on potential rock and roll conditions.

Special Assignment B Light vs. Heavy Geometry Car Testing

Progress to Date: An experiment was conducted in September, 1985 on Chessie track, where five different track geometry measuring vehicles were run at different speeds over a section of instrumented track. The results showed that geometry cars produced loaded track deflections that were typically less severe than those produced by a 100 ton car. This requires an adjustment factor on track defect thresholds that varies with geometry car weight and speed. The results also pointed to the wisdom of measuring gauge just ahead of the leading axle.

These results were presented at the 1986 Annual General Meeting.

Future Work: It is intended to follow up with a Phase II test to provide data to enable Subcommittee 4 to develop track geometry car specifications.

Special Subcommittee on Research and Seminar Needs

Objective: This Subcommittee consists of all Subcommittee Chairman and the Committee executive. It is intended to prepare a research needs statement each year for the AREA and to investigate the need for and feasibility of education seminars to the industry on track measurement and inspection issues.

Status: This Subcommittee is awaiting the results of Subcommittee 3's survey of needs for new technology before preparing a list of research priorities.

The Subcommittee is also developing plans for a seminar on the potential for Automated Track Inspection.

Excerpts From 1986 Annual Report of A.R.E.A. Committee 3 — Ties and Wood Preservation

J. B. Miller, Chairman

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

All of these assignments are active with the exception of assignment (c) which is the possible revision of cross tie design and spacing. All of these assignments are on-going assignments with exception of (c) & (d). We have recently submitted revised specifications for switch ties for consideration and approval under assignment (a). Under assignment (d) we have also submitted recommendations concerning the dating of ties prior to treatment. I do not recommend any change in these assignments.

Sub-Committee 2 — Wood Preservatives and Preservative Treatment of Forest Products

We have been following this development very closely, however, there seems to be a definite lull in activity in this field. In 1985, we made major revisions to parts 5 & 6 of the manual which would be covered by assignments, (a), (d), (e) and (f). As far as assignment (b) - new preservatives is concerned, we are always keeping abreast of any developments. I feel all of these assignments are on-going and I do not recommend any of them be dropped, however, we may be able to consolidate some of these assignments after further analysis.

Sub-Committee 3 - Service Records of Forest Products

Assignments (a) & (c) definitely warrant keeping as they are on-going and we should keep abreast of these activities. I do question assignments (b) - marine organisms and (d) - imported cross ties.

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

Assignments (a), (b), (e) and (f) are active. There has been no activity in assignment (c) - one step seasoning and treating method developed by AAR-NLMA and (d) - feasibility of using atomic energy to retard decay in forest products. I recommend that these two assignments be dropped and that the remaining assignments be continued as I feel that there will be further developments in these fields.

Excerpts From 1986 Report of A.R.E.A. Committee 4 — Rail

B. D. Sorrels, Chairman

Subcommittee 1

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

Ad Hoc Committee on Profile Grinding - This assignment was made some 4 or 5 years ago and progress has been made since that date. Interim reports were presented at our Spring Meeting in Hershey, PA, and this study is ongoing.

Qualification Testing: The work continues on the evaluation of flash butt welds. The 132-lb. rail welds have been made and slow bend tested and the 115-lb. rail welds are 75% completed and scheduled for slow bend test. More testing is planned and the metallurgical microstructure analytical work is in progress.

High Strength Rail Welding - This is a new Ad Hoc Committee, assigned to study the significant problems associated with hardened rail end batter at the weld. This Ad Hoc Committee has collected and presented field experience and test data from FAST. Further work is required by this committee and its work will continue. We feel that the benefits to be derived from this assignment are significant and badly needed by the industry.

Subcommittee 2

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

The rail suppliers have furnished the rail committee with survey results on rail symmetry, rail height, base width and flange thickness of rail producing mills. These statistics, have been utilized by our subcommittee 5 in preparing revisions to our rail specification. Important functions of this particular committee include ongoing research work on ultrasonic testing, stamping, side sweep, long rail lengths and tolerances, waviness, twist, macroetch standards, symmetry, flange thickness and base flatness.

Considerable progress has been made with our Ad Hoc Committee on macroetch standards, with interim reports being presented. It is hoped that this work will progress to a point to where specifications can be written to cover macroetch standards in the very near future. We feel that the work of this subcommittee is quite important to AREA and to the industry as a whole.

Subcommittee 3 - Rail Statistics.

Rail statistics is an ongoing study of quantities of welded rail laid on various railroads in the United States as well as failure data covering various types of rail failures occurring.

This particular committee has failed to produce all of the required statistical data for the past several years. This committee has been unable to obtain much of the required information due to numerous difficulties being experienced in this particular area. These difficulties include the casting off of portions of their lines by some major railroads, and our inability to catalogue this information, from the smaller railroads. Railroad mergers have tended to confuse the statistics for the new larger railroads and that some railroads indicate that they are unable to produce these required statistics with any degree to reliability. We have also had some difficulty with some very large railroads, in securing any type of report relating to the required statistics, and the absence of this type of reporting tends to negate the benefits of the remaining statistical data.

We have corresponded with our headquarters relating to a relinement of this committee, outlining several areas of statistical data which we recommend be deleted, and indicated what types of information we feel we will be able to continue.

Subcommittee 4

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

This committee has circulated a questionaire requesting procedures and experiences in making repairs to the running surface of alloy rails of different types. At this time the reporting railroads have indicated very limited experience with the alloy rails. The questionnaire will be updated and recirculated. We feel that this particular subcommittee can produce some worthwhile information relating to this subject, which will be of benefit to AREA as well as the industry.

Subcommittee 5

Rail Specifications research and development.

This is a very important subcommittee and has been most active during the past several years. The subject is continuing, and currently the committee is working on several very important matters inclusive of the following:

1. Collaborating with subcommittee 2 in preparing specifications for macroetch standards. It is hoped that the microetch standards will replace the drop test and the nick and break test as a method for eliminating rails with excessive segregation, non metallics or lack of soundness.

2. Revision of inspection and classification of secondhand rail for welding, pages 4-2-6.5 and 4-2-6.6 of the manual.

3. Review and update test reports and include as part of the specification.

4. Develop specification for base flatness, which has been completed and will be circulated among the membership of AREA Committee 4 for letter ballot in the very near future.

5. Include a statement indicating acceptable martensite levels, for rail steels.

6. Develop specification for tools for measuring rail tolerances.

We believe that the assignment of subcommittee 5 remains to be very important to our committee, and recommend that continuation of this committee and their work toward altering and improving our specifications for steel rails.

Subcommittee 6

Joint bars, design specifications, service tests including insulated joints and compromised joints.

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

This subcommittee has been assigned the task to revise the entire section of our manual dealing with joint bars, bolts and nuts. Several drawings no longer apply, sizes need to be added and physical data needs to be revised. This work is progressing.

We feel that subcommittee 6, with its new assignment, is progressing, and its work should benefit AREA.

Subcommittee 7

Effects of heavy wheel loads on rail.

Subcommittee 7 has an ongoing study relating to the effects of heavier cars upon the fatigue life of rail steel. This committee has presented several interim reports, and its study is continuing. We believe that this work will be of considerable benefit to AREA and the railroad industry as a whole.

Subcommittee 8

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

This committee has worked on this assignment for several years, and presented a paper for inclusion into the AREA manual. The board discovered some possible improvements to this report, and this committee is now in the process of rewriting this particular paper for inclusion in the manual. We expect this assignment to be complete within the next several months.

Excerpts From 1986 Annual Report of A.R.E.A. Committee 5 — Track

N. M. Clark, Chairman

Subcommittee A - Recommendations for Further Study and Research.

a. A recommended research study for longitudinal forces in track has been recommended to the AREA Board.

b. Subcommittee 7 would like to poll the railroads in the country to see if a specification is required for reworked rail anchors.

Subcommittee B - Revision of Manual

a. Review anchor pattern. Ballot is presently out on this revision to Manual. Should be complete in 1986.

b. Review anchor application and maintenance. Working with Subcommittee 7 on this assignment. Should complete in 1987.

c. Review rail laying temperatures for CWR, joint with Subcommittee 7. A second letter ballot will be out this fall. Should complete in 1987.

Subcommittee 2 - Track Tools

a. Review inclusion of new and additional Track Tools. This is a standing subject.

b. Specifications for abrasive wheels. This assignment complete and was published in Bulletin 704.

Subcommittee 4 - Track Design

a. Elastic rail fasteners.

Chairman L. E. Daniels has drafted a comprehensive specification which has drawn a lot of comment from some quarters. Review of the comments are due at the September meeting. Should complete in 1987.

b. Hold down fastenings, wood ties. This is moving slowly but studies are underway on several railroads at this time. Should complete in 1988.

C. Tie plates - wood ties. This is a standing assignment.

Subcommittee 5 - Turnout and Crossing Design

a. Review guard rail lengths. This subject is about 2 years old. We should complete it in 1987.

b. Investigate worn wheel ramp. This was complete and plans redrawn in 1986.

c. Investigate fastening agents for trackwork. This is an old subject but I recommend keeping it alive due to the many different fasteners coming into the market area.

d. Investigate use of gage plates throughout the turnout. Several railroads are now doing this and recommendations should be made in 1988.

e. Develop specifications for explosion hardening frogs. This has been changed and rather than develop a specification, we plan to allow the manufacturer to harden the frog by whatever means he desires. Should complete in 1987.

f. Maintenance parameters on frogs and switches. I recommend that Subcommittee 7 get involved here.

g. Complete.

Subcommittee 6 - Track Construction

a. Editorial changes to the CWR sections of the Manual are in order. Should be complete in 1987.

Subcommittee 7 - Track Maintenance

a. Study rail lubrication. Subcommittee 7 is involved with the AAR and Committee 4 on rail lubrication.

b. New subject. Maintenance on switches and frogs - with Subcommittee 5.

c. Collaborating with Subcommittee B on anchors and CWR temperatures.

Subcommittee 8 - Criteria for Track Geometry.

a, b, c, - All assignments are awaiting replies to questionnaires from railroads.

Excerpts from 1986 Annual Report of A.R.E.A. Committee 6 — Buildings

J.G. Robertson, Chairman

Subcommittee A: Recommendations for Further Study and Research

Items that are being considered for new subjects are:

1. Design Criteria for Wheel Shops
2. Management of Fixed Property

Subcommittee B: Revision of Manual

The report covering Design Criteria for Diesel Locomotive Facilities has been completed and sent to the membership for vote. This report will update the existing Part 4 in the Manual.

Subcommittee 1: Design Criteria for CTC Dispatch Facilities

An outline of the report has been approved by the committee. Construction plans, showing the details of recent facilities, are being sent to the subcommittee chairman. It is expected that this report will be completed in June 1987 and become a part of the Manual.

Subcommittee 2: Design Criteria for Car Repair Facilities

An outline of the report has been reviewed and will be progressed to cover one spot shops and light and medium repairs. Construction drawings of recently built shops from various railroads are to be forwarded to the subcommittee chairman. This report will replace the existing Part 3 in the Manual and is expected to be completed in June 1987.

Subcommittee 3: Design Criteria for Railway Office Buildings

This report is being progressed to update the existing Part 2 of the Manual. The updating of the portion pertaining to electrical requirements has been completed. It is expected that this report will be complete by June 1987.

Subcommittee 5: Architectural Design Completion

This subcommittee has been inactive since the last AREA sponsored design competition. The work of this subcommittee is "on going" and the members will collaborate with Committee 24 as necessary.

Subcommittee 6: Energy Conservation and Audits

This subcommittee report is complete except for a few minor modifications and will be sent to the full membership for approval in the near future. It is intended that this report will become Part 5 in the Manual and the existing Part 5, TOFC-COFC Facilities, will be deleted.

Those Who Labor On Rails Yet To Be

In the nineteenth and early twentieth century, it was common for railway engineering people to be employed by railway companies that had not yet run a train. Location engineers, surveyors, and construction engineers were often at work many years before the trains ran, and many worked hard at projects which for various reasons never came to fruition.

This situation has again arisen where many A.R.E.A. members are employed in designs and plans and studies for rail systems not yet in operation, primarily in rail transit and high speed passenger rail. New rail transit projects in cities like Dallas and Los Angeles employ many engineering professionals, though they have no vehicles or even track yet. But these engineers can look to recently completed projects in many North American cities for inspiration in their work.

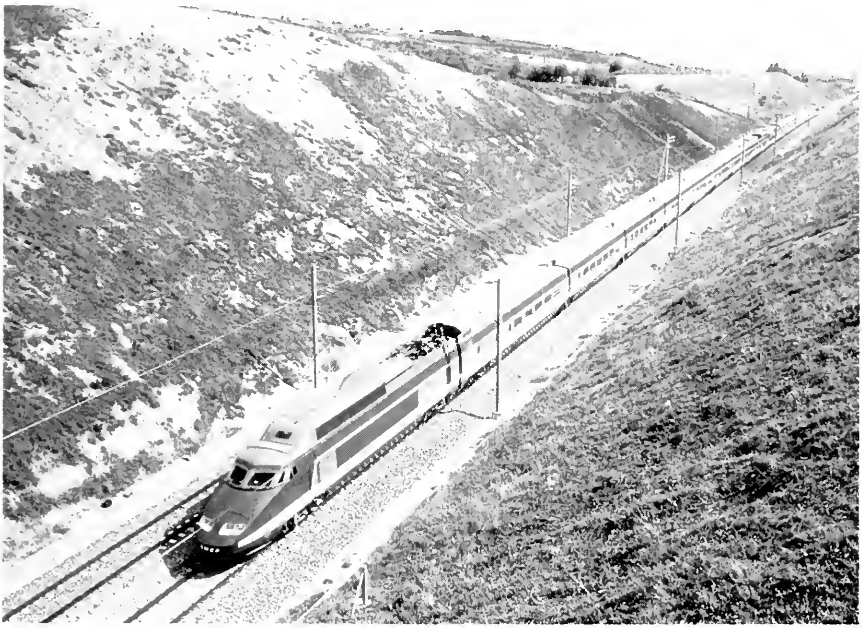
Those employed on projects for high speed (say, over 150 m.p.h. to choose a figure) rail passenger systems have no North American facilities to use for inspiration and must look overseas to find daily high speed rail operation. Opinions among railway engineering professionals about the possibility of successful use of high speed passenger rail in North America range from highly optimistic to deeply skeptical, and of course only the future will determine who is right.

The French 170 m.p.h. T.G.V. system, in partial service since 1981 and full service since 1983, is beginning to provide some hard data about passenger rail service over 150 m.p.h. Information on it is presented here in the following two articles in the absence of equivalent North American information.

The photo above shows work in progress in the summer of 1986 before rails are laid on the San Jose, California rail transit system, one of many new rail systems recently constructed, under construction, or in planning in North America.

AN INTRODUCTION TO THE FRENCH TGV SYSTEM

Excerpts from a Presentation by A. De Tessières at the A.R.E.A. Modern Rail Conference in Vancouver, Canada Oct. 2 1986



The new 242-mile (390 km) very high-speed Paris-Lyon line was commissioned partially in 1981 and in full in 1983. It is dedicated exclusively to passenger traffic and was designed with grades of 3.5% and for a speed of 187 m.p.h. (300 k.p.h.).

97 TGV passenger trainsets are operated over the line in routine services at 168 mph (270 km/h); they also operate well beyond the new line over 1,010 miles (1,626 km) of old lines to Lille, the Alps, the Mediterranean coast and Switzerland at speeds ranging from 60 to 125 mph (100 to 200 km/h).

In 1985, TGV trainsets carried 14.7 million passengers and earned 3,500 million francs in revenue; expenditure, including depreciation and financial charges, totalled 2,760 million francs. Between 1980 and 1985, total rail ridership over all routes with TGV services has grown 57%. Most of these additional passengers have come from automobile and air traffic. However, possibly as much as 3 million was "induced traffic", truly TGV generated.

The 242-mile (390 km) new high-speed line branches off the old line 19 miles (30 km) south of the Paris-Gare de Lyon station and connects up to the old line 5 miles (8 km) north of Lyon. (see map page 397).

The principle of compatibility with the existing network ensures that high-speed rolling stock can be run not just on new lines where track geometry has been designed for new performance levels, but also on the lines of the existing network. On the latter, train speeds are lower of course because of the constraints of track layout and conventional lineside signalling.

The advantages of this approach are that then high-speed rolling stock can use existing train terminals which are well integrated into urban tissue. Had non-compatible stock been used, planners would have been restricted to: either a new right-of-way built right into the very heart of Paris and Lyon, a solution which is both very expensive and extremely difficult because of environmental constraints, or the terminals would have had to be sited at the outskirts of built-up areas, but then passengers would have to change modes and this makes rail transportation much less competitive, especially when air transportation is a rival mode.

Between the outskirts of Paris and Lyons, a new line dedicated to passenger traffic allowed optimizing the design of the new line to suit the requirements of passenger traffic alone. If slow freight trains and high speed passenger trains were to be run on the same line, curve radii would have to be much larger and it would not be possible to have the steep grades which are extremely important in keeping down the cost of new right-of-way, especially in hilly areas. Because the new line was designed specifically for TGV trains alone, it was possible to have grades of up to 3.5%. As a result, no tunnels whatsoever had to be built and fewer and shorter bridges and viaducts were needed. There are only 10 viaducts over the entire new line, totalling 1.2 miles (2 km) altogether. And the rail distance between Paris and Lyon has been cut from 318 miles to 264 miles (from 512 km to 425 km), i.e. by nearly 20%.

Between September 1981 and December 1985, 135,700 trains have run on the new line and TGV trainsets covered 67 million miles (108 million km). At present each TGV trainset covers 217,500 miles (350,000 km) per year on average.

The world rail speed record of 236 mph (380 km/h) set by a production trainset in February 1981 on the new line was further proof that TGV passengers travelling in revenue services at 168 mph (270 km/h) have a very large safety margin.

TGV passenger revenue in 1985 totalled 3.500 billion francs. Operating expenditure represented only 34% of that amount, leaving a remaining gross operating surplus of 2.300 billion francs. After depreciation and interest charges for rolling stock and the new line have been deducted, the TGV accounts for a net contribution to French Railroads' overheads and costs totalling nearly 21% of TGV revenue.

	Percentage of TGV Revenue
— Operating and maintenance expenditure	34%
— Depreciation and interest charges for rolling stock	13%
— Depreciation and financial charges for fixed plant	32%
— Net surplus	21%

A net surplus was obtained as early as in 1984, which was the first full year of operation of the entire new line.

The internal rate of return for the TGV Southeast system is proving to be 15% for French Railroads and 30% for the community as a whole.

French Railroads did not receive any subsidies for the TGV Southeast project and all of the capital required came either from the company itself or was borrowed on the financial market. French Railroads alone are responsible for interest on loans and amortization for both the new line and TGV trainsets.

Paper From A.R.E.A. Modern Rail Conference
Vancouver, British Columbia Oct. 1-3, 1986
Track and Structure Maintenance For 170 M.P.H. on the New Paris-Lyon TGV Line

by Jean-Pierre Pronost
Chief Civil Engineer
Head of S.N.C.F. Track and Structures Department

The new High Speed Line between PARIS and LYON has been in operation since 1981. This talk puts the emphasis on track design, and maintenance which enable the S.N.C.F. (French National Railways) to ensure the high standard of maintenance required by high speed operations while minimizing costs.

1 - TRACK DESIGN

Investigations and tests carried out by S.N.C.F. between 1970 and 1976 culminated in the development of a track technology concept specifically adapted to traffic moved at high speeds on the new high speed Paris-Lyon line.

It is interesting to note that dynamic overloads borne by a line worked at 170 miles/h are largely caused by unsprung weights. While the dynamic load, per wheel, of a 17-ton axle is comparable to that of the wheel of freight wagons with 20-ton axle-loads running at 60 miles/h, the most aggressive frequencies are nevertheless quite different, amounting to 3 to 4 cycles for the freight axle load as compared with 40 to 50 cycles for a TGV at 170 miles/h. This corresponds to critical defects with wavelength of between 67 and 71 inches.

Likewise, ballast-transmitted stresses range from 0.8 g for a locomotive with 21-ton axle-loads at 85 miles/h to 1.4 g under a TGV axle at 185 miles/h.

The track on the New Line consequently had to allow for these test results, which explains the adoption of a structure consisting of:

— a UIC-60 (about 120 lb/yd) heavy rail to ensure proper distribution of vertical and lateral loads. The geometrical quality of rails and welds have been carefully defined to cater particularly for routine defects presenting a long wavelength (of between 59 to 79 inches) after rolling and planning. In fact, the maximum permitted tolerance was 0.3 mm* for a 63 inch base,

— a 9 mm grooved rubber pad (instead of 4.5 mm on conventional track), so as to reduce the specific frequency of unsprung weights and absorb vibratory energy more effectively,

— a 540 pound, type U41 two-block concrete sleeper with good track anchoring in the ballast, and fitted with NABLA fastenings guaranteeing excellent maintenance - good clamping-force retention, over the years, including cases where a 9 mm pad is used.

— extra hard, extremely thick ballast (12 inches under sleepers except 10 inches under inner rail stretch in curves) guaranteeing good resistance to attrition caused by dynamic overloads.

In the case of switching equipment, the model chosen is of the UIC 60/A 61 type with symmetrical inner rail stretch and movable nose crossing. The switching equipment is of two types: 1/46 and 1/65 frog angles respectively, allowing for crossing speeds of 100 miles/h and 140 miles/h on diverted track.

The New Line consists of about 160 miles of double track (including feeder lines to the existing network) and 135 turnouts, 87 of which incorporate movable nose crossing - 60 of type 1/46, and 27 of type 1/65.

The mean traffic load borne ranges from 35,000 to 45,000 tons per day depending on the track sections. This identifies the line with UIC groups 3 and 4, although this classificaton today is no longer relevant to lines worked at operating speeds above 120 miles/h.

II - ORGANIZATION OF TRACK MAINTENANCE WORK

The 9 maintenance teams spread over the whole line are together made up of 10 supervisory staff and 97 field staff.

Each team is provided with one truck housing the tooling equipment, one or two emergency vans, and a light vehicle.

As from mid-1986, these logistics resources will be increased, on each section, by a heavy-duty and powerful track motor car incorporating a handling arm. This car is designed to ferry staff to the worksite, and technical equipment to places with difficult road access.

These installations all incorporate radio equipment allowing intercommunication among themselves and the PARIS Central Control. As a matter of interest, locomotives running on this line and track cars and tamping machines are fitted with transducers enabling them to pick-up signalling information in the cab, thus ensuring the safety of train operations.

Maintenance operations are performed at night, during the 6 hours (or thereabouts) when no trains operate in revenue service. During this period, only 2 TGV trainsets owned by the Post Office are worked, occasionally using one track equipped for two-way working.

III - TRACK INSPECTION

The Permanent Way Department is given track possession for an extra 90 minutes during daytime hours to monitor specific spots on the track (points and crossings in particular) and organize night work.

*Tolerances in mm have been left in metric units. (One mm is approximately equal to 0.04 inches)

Installations are monitored through inspection rounds (on foot), through on-track checks during daytime traffic breaks, through lineside checks, or again through checks conducted from the driving cab or rear cab of a TGV trainset, based on the following cycles:

a) Routine on-foot inspections

- Track: every 10 weeks by the line foreman
- Switchgear: every 5 weeks
- Track approaches (fencing, embankments, ditches, etc.): every 5 weeks
- General inspections by the District Manager: every month

b) Inspections on board TGV-cab

- By the District Manager every 2 weeks.

c) Special inspections on foot

- Each year, at the start of the extremely-warm period, generally in early May. This is routine practice on S.N.C.F. for track with continuous welded rails
- When weather conditions are exceptionally bad

Maintenance planning is determined in the light of the results of quarterly checks performed on board a track inspection car. The first ultrasonic rail check to detect possible rail fatigue will be performed at the end of 1986 and will subsequently be conducted annually.

In addition, a weekly vertical and transversal accelerographic recording is performed aboard a trainset used in revenue service.

These different diagnosis methods make it easier to assess the evolution of the geometrical quality of track and turnouts, and consequently to trigger track levelling and realignment operations, as necessary.

In addition, the switchgear inspections and controls carried out sometimes provide an opportunity to consolidate the bolting system and rod assemblies, or to adjust and replace minor equipment components.

Other than the switches, we can see that track maintenance work is primarily concerned with the geometry and is carried out generally by means of modern tamping and aligning machines owned by contractors.

IV - TRACK GEOMETRY MAINTENANCE

Track geometry is basically monitored by means of MAUZIN cars, which issue three types of documents:

— The standard MAUZIN chart, based on a 20 cm per km scale,* reproduces the defects usually measured by the car on the basis of 12,20m length for levelling defects and 10 m for alignment defects, to which we can add track twist, cant deviation and gauge. This chart, which gives a precise description of fairly short-length defects, is always an essential document because these defects correspond to vibration frequencies for vehicle body structures at 160-185 miles/h, in addition to being a source of discomfort.

— An "extended-base" chart on a 10 cm-per km scale reproduces the standard levelling and alignment of the two rail stretches, and also gives extra information for evaluating the levelling and alignment defects for the mean of the two rail stretches over 30 m lengths. This chart consequently provides the possibility to determine the adequateness of the longitudinal profile and cross-sectional layout for long-length defects.

* This section left in metric units because the inspection cars record in this system.

— Another chart, more commonly known as the "MAUZIN summary chart", is laboratory-produced in deferred time on a 1 cm-per-km scale, and gives the mean deviation, over a 300 m rolling section, for the following parameters:

- longitudinal level
- cross level
- alignment
- gauge of track

measured on a base of about 10 m. It also gives an evaluation of rail geometry defects in the 1.60 m wave-band, which is obtained through axlebox acceleration measurement on the MAUZIN car in the 0-150 cycle waveband.

This summary chart, by quantifying the different values, enables us to monitor the evolution of track-geometry quality, and to program continuous rectification work when long track sections are involved.

These consolidated values must be assessed by comparison with two limits: a lower limit representing the minimum objective to be achieved after a maintenance operation, and an upper limit, corresponding to the level which must not be exceeded in order not to risk major deterioration in comfort levels or acceleration of track degrading. In fact the tamping and aligning process is generally started as soon as the consolidated recording of longitudinal level reaches the 0.6 mm mark (see TABLE).

It is also seen, from an analysis of figure 5, that the improvement obtained through tamping on the longitudinal level (Δ NL) is "optimal" for an NL (longitudinal level) of about 0.6 before intervention, the gain being approximately 0.25. By contrast, since the ΔNL increases only slightly when the quality is allowed to deteriorate beyond 0.6 - 0.7, the NL coefficient cannot be brought back to below the desired mark of 0.4 if tamping work is delayed for too long.

TABLE 1
Values produced by consolidated recordings
(Mean deviation over 300 m)

	Lower limit (mm)	Upper limit (mm)
Longitudinal level	0.4	0.8
Cross level	0.4	0.6
Alignment	0.9	1.4

In addition, intermittent operations using light tamping equipment - or possibly a heavy-duty tamping machine if justified by the track length to be processed - are triggered when the defect limits specified in TABLE II are exceeded:

TABLE II
Values obtained with MAUZIN recordings
(standard bases and extended bases)

Recording	Measurement base (m)	Peak-to-Peak defect	
		Current value (mm)	Isolated defect (mm)
Standard longitudinal level	12.20	5	10
Standard alignment	10	7	12
Extended-base longitudinal level	31	8	10
Extended-base alignment	33	8	12

In fact, these values do not represent absolute tolerances: they are rather limits which staff in charge of maintenance must monitor closely.

Moreover, observations of MAUZIN recordings on standard and extended bases serve to define the relevant corrective process:

— when the track presents defects with long wavebands, tamping-alignment is carried out on absolute bases or by reference to pegging,

— if, on the contrary, the defect chart on extended base does not reveal long-length defects, the machine is used in automatic mode, which allows defects of up to approximately 30 m wavelength to be corrected.

As a matter of interest, the track maintenance machines used on the New Line incorporate a special device to cope with alignment defects of extra long wavebands (40-50 m). This system, involving the "layout compliance control (KRT)" measurement, enables the basic leveling length to be raised to about 35 m.

Except during the winter period (October 1st to April 1st), maintenance-tamping operations are systematically supplemented by dynamic stabilization aimed at delivering, in time for the following morning, track sufficiently stabilized to allow working at revenue speeds of 170 miles/h.

It has also been found that the rail-surface condition had a decisive influence on the pattern of development of the geometrical quality of track.

Although no rail corrugation has ever been observed, some original defects are nevertheless inevitable despite all the precautions taken during the rail-planning and welding process. Next, under operating conditions, some wheel burns do become apparent caused primarily by work trains, and even a few superficial marks brought about by crushing of ballast particles mainly during the winter period. When the presence of these geometrical defects is observed, the running surface must be treated right away.

These observations led S.N.C.F. into developing a specific rail grinding policy for the New Paris-Lyon high speed Line. In those areas recording rapid deterioration of the rail surface, a grinding operation based on an appropriate number of applications is sufficient to slow down the rate of subsequent rail geometry deterioration. Experience has shown that tamping work is reduced by 50% on average over the years, following rail grindings which must preferably be carried out shortly after maintenance tamping in order to guarantee greater efficiency.

The overall cost benefit of track-levelling maintenance is consequently increased as a result, since the mean time-interval between any two tamping operations has now stabilized to about 2 years.

V - ANNUAL TRACK MAINTENANCE COST

Costs identify with three main items:

— S.N.C.F. labor costs and general overhead.

— Supply of materials and tooling.

— Work performed by contractors.

The following table shows the overall costs recorded for 1985:

YEAR 1985
HIGH SPEED LINE TRACK MAINTENANCE COSTS
U.S. DOLLARS*

I - SNCF labour costs and general overheads:	
• SNCF labour costs	1,974,000
• General overheads, administrative, supervisory and management costs	653,000
II - Supply of materials and tools	
• Ballast, sundry equipment, tools, vehicles, etc.	355,000
III - Work performed by contractors	
• Tamping-lining, running-track stabilization	1,775,000
• Tamping-lining of switchgear	170,000
• Grinding	483,000
• Ancillary work (undergrowth clearance, ditch cleaning, etc)	170,000
TOTAL	5,580,000

(Approximately $11,000 per track mile and 1.5% of gross revenue)

*1MF = 0.142 US $

The mean annual track-maintenance budget consequently amounts to some 11,000 US per mile of track, which is quite reasonable given the high standard of maintenance and the traffic volume handled by the New Line. There is no denying, however, that certain operations involving the partial renewal of materials will have to be envisaged in the medium term, this being justified by the traffic volume borne by the line since its opening. Experience gained with other main lines of the S.N.C.F. network suggests that the following operations will need to be carried out:

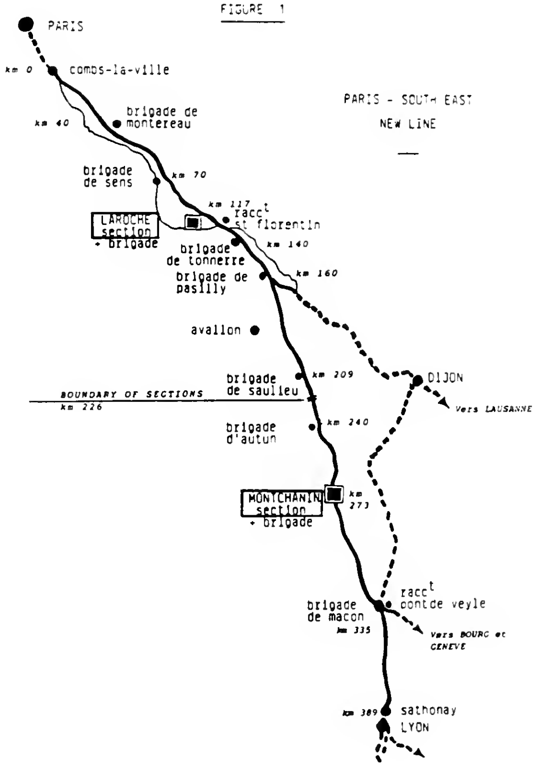
— partial ballast renewal after 250-300 million tons, in other words around 1995,

— rail and fastening renewal after 500-600 million tons, in other words between 2000-2010.

It is too early for an evaluation of the future pattern of development costs to be attempted. The fact nevertheless remains that for a homogeneous line worked - admittedly at high speeds - exclusively by passenger trains with axle-loads limited to 17 tons, current maintenance costs remain quite low, having represented in 1985 about 1.5% of total revenue from traffic on the New Line.

As a consequence of the commercial success and profitability of the new line between PARIS and LYON, we are now building another dedicated line, West of PARIS, with one branch to South West and one branch to Brittany. This new line will be in operation in 1989 and 1990.

FIGURE 1



In-Track Performance Test of Geotextiles at Caldwell, Texas

(A.A.R. Research and Test Dept. Report No. R-611, December 1985)

by
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and
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Soil and Material Engineering

1.0 INTRODUCTION

In November, 1977, an extensive field investigation of geotextile performance and the associated influence on track behavior was begun, as a joint project of the Monsanto Corporation and Southern Pacific Railroad. The test site was located in Caldwell, Texas, in an area with significant track maintenance problems due to poor subgrade performance. The subgrade soil is comprised of a medium to soft consistency, highly expansive clay, which typifies some of the worst soil conditions under which geotextiles are placed.

The geotextiles were installed in a new siding constructed alongside the main line track. New track construction was selected for the test, to eliminate problems related to ballast pockets and undercutting programs that would have been experienced if the fabric and instrumentation had been placed in existing track. The main line carries about 10 MGT per year, which is considered to be moderate tonnage for a main line track.

The test was planned with the objective of determining the extent to which fabrics perform the anticipated functions of:

(1) Reinforcement,

(2) Subgrade moisture transport,

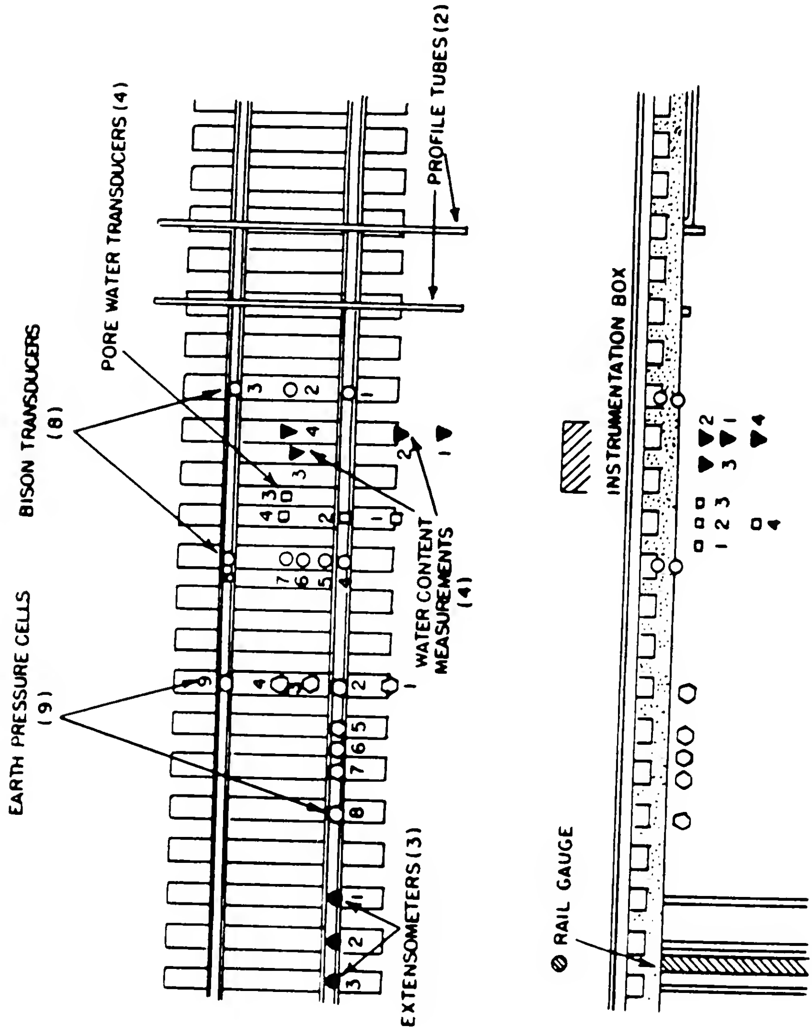


Figure 1. Schematic Diagram Showing Typical Subgrade Test Instrumentation.

(3) Filtration, and

(4) Separation.

Extensive instrumentation was required in order to differentiate the role that each mechanism played in a given test section. Figure 1 illustrates the subgrade instrumentation that was installed in each section.

The existing and design grades at each of the six individual test sections are shown in Figure 2. Test Sections 1 through 4 were constructed with nonwoven fabrics placed on the compacted subgrade. The properties of the geotextiles are listed in Table 1. Section 5 was a control section with no fabric, and Section 6 was a cement-stabilized zone. Section 6 was used to compare the performance of a conventional, but expensive, method of subgrade stabilization with the performance of the various fabric sections. The length of each of the fabric sections and the cement-stabilized section was 300 feet, whereas the control zone was only 150 feet in length. The control site was made shorter because this track section might fail or experience a large amount of settlement.

The natural soil had a range of liquid limits between 50% and 85%, and a plastic index of between 27% and 55%, and is therefore a CH type soil (inorganic clay of high plasticity) under the Unified Classification System. The natural soil was about 95% saturated. Before any construction occurred over the test area, the site was rough graded, and an eight-inch layer of clayey loam was placed and compacted over the existing subsoil for all six test sections. The compacted soil layer is classified as a CL soil (a silty clay of low plasticity). The subgrade was then graded to establish the profile shown by the line marked "Soil-Ballast Interface" in Figure 2. The surface of the compacted soil layer was lightly cement-stabilized over the entire test area to provide a zone of intermediate strength between the ballast and subgrade.

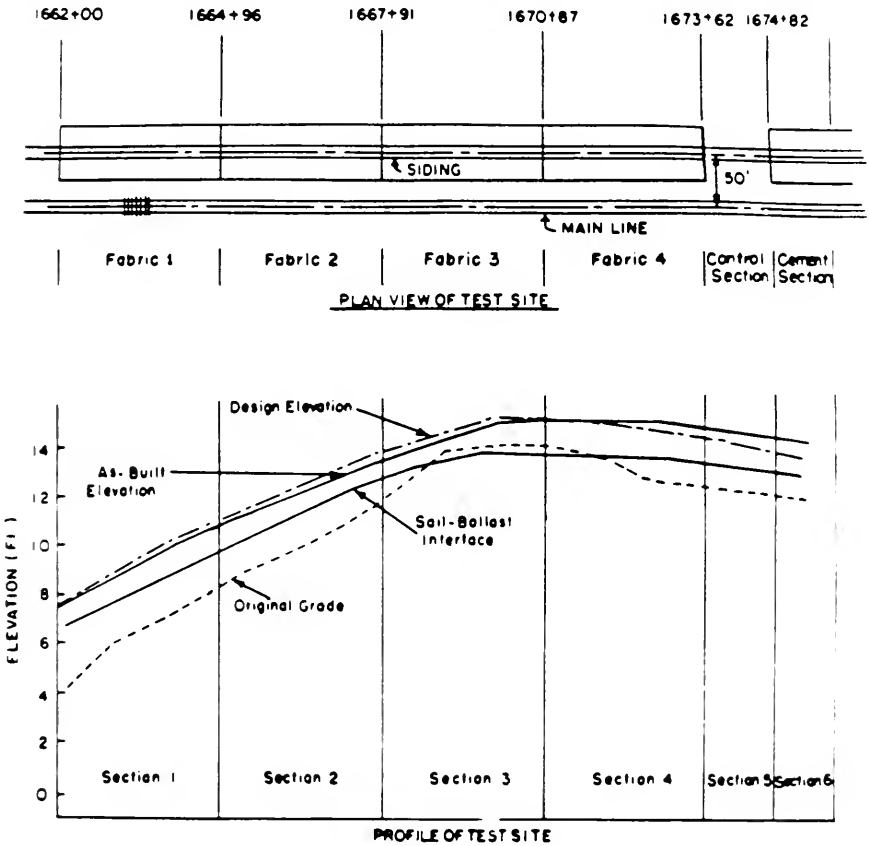


Figure 2. Caldwell Test Site Configuration.

Table 1

Physical Properties of the Caldwell Test site Geotextiles

Property		Fabric 1	Fabric 2	Fabric 3	Fabric 4
Basic Weight, ounces per square yard (osy)		10.7	10.7	6.1	6.7
Thickness at 0.03 bar, mils		173	99	22	78
Porosity, %		91	90	60	92
Density, kg/m^3		83	144	364	114
Puncture Strength, lb		113	143	74	88
Puncture Toughness, lb		40	34	24	25
Burst Strength, psi		344	458	270	311
Grab Strength, lb	MD (Note a)	165	279	233	238
	TD (Note b)	271	301	225	184
Apparent Elongation, %	MD	129	66	61	63
	TD	112	61	75	75
Toughness, lb	MD	106	92	71	75
	TD	152	92	84	69
Trap Tear Strength, lb	MD	62	114	76	95
	TD	88	109	102	86
Abrasion (Grab Strength), lb		104	177	184	71
Lateral Permeability,					
at 0.24 bar, cm/sec		0.27	0.32	0.06	0.38
at 2.00 bar, cm/sec		0.08	0.13	0.01	0.14
Normal Permeability, cm/sec		0.57	0.45	0.02	0.44
liter/sec/cm^2		0.022	0.022	0.004	0.034
Equivalent Opening Size (EOS)		50	-	200	-
Denier		7	7	12	7
Polymer		Polypropylene	Polyester	Polyester	Polyester
Structure		Needled	Needled	Thermal Bonded	Needled

NOTES:
a: MD = Machine Direction
b: TD = Transverse Direction

Field California Bearing Ratio (CBR) tests were performed on the compacted soil at three locations within each test section. The average CBR values at 0.1 inch penetration for the six sections were 24, 23, 21, 20, 32, and 15, respectively. The CBR values were slightly greater than would be expected for the compacted clayey loam, due to the surface cement stabilization.

Eight inches of ballast was placed in the test sections after each of the fabrics were placed. No subballast was used. Section 6 had the ballast resting on 12" of cement-stabilized rock screenings.

2.0 ENVIRONMENTAL FACTORS

2.1 Weather Data

Daily weather information regarding rainfall, humidity, and temperature extremes were collected by Southern Pacific personnel stationed at the Caldwell depot. These data could be used to help explain the instrument readings, in those cases where the track behavior changed for reasons other than traffic loadings. Weather data were also collected from the nearest National Weather Service station, 25 miles to the north at College Station, Texas. Monthly rainfall accumulation data for both Caldwell and College Station are shown in Figure 3, and it can be seen that the peak cumulative monthly rainfall totals do not exceed 12 inches. The yearly (1979) cumulative rainfall for Caldwell and College Station were 61 and 51 inches, respectively. The near vertical slopes on many of the monthly histograms are caused by frequent cloudbursts that can produce up to five inches of rain within a single hour. Such a large amount of water cannot be absorbed by the subgrade, and a large percentage leaves the site as surface runoff.

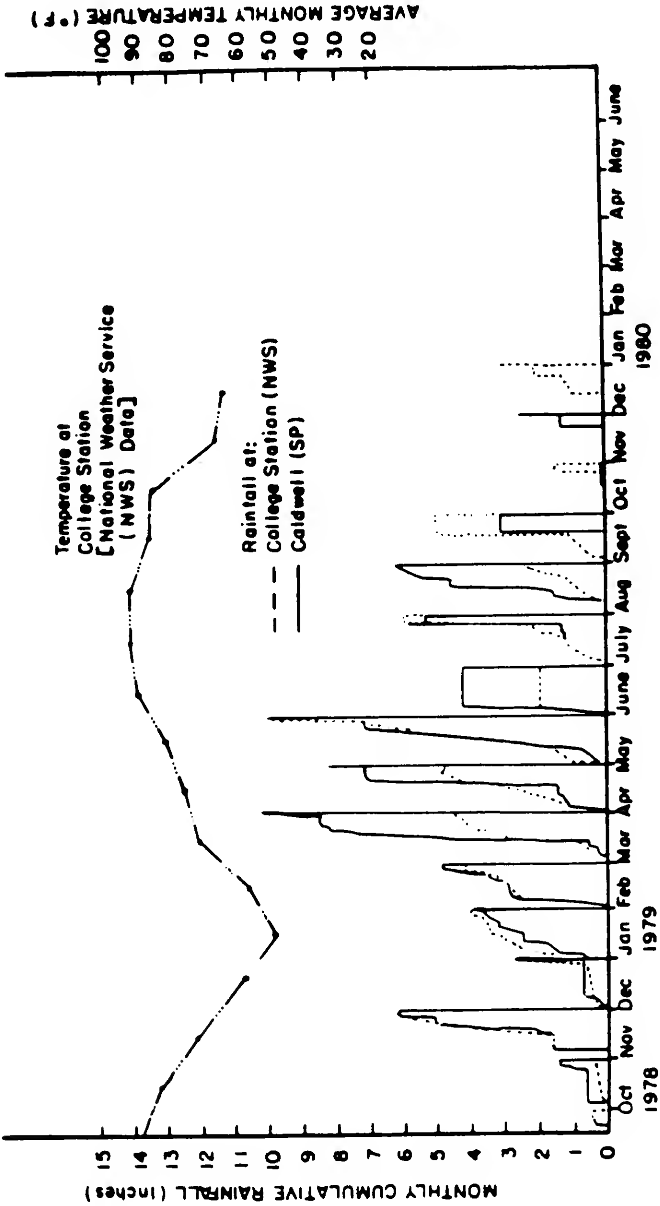


Figure 3. Weather Data for Caldwell and Nearby College Station, Texas.

2.2 Effects Of Expansive Soil

Soil which greatly increases in volume with the addition of water is called swelling or expansive soil. Although all clay soils will swell to some degree, the amount of volume-increase depends, in part, on the clay mineralogy. The clay minerals that are predominant in eastern Texas are known to have a high potential for swelling.

The effects of swelling soil were seen in the top-of-rail surveys and soil moisture measurements obtained periodically over a period of one and one-half years. Upheaval of the track was observed after a hard rain, but the effect of this soil swelling upon the dynamic instrument response should not have been appreciable.

2.3 Track Loadings

The inital track loadings resulted from running revenue trains over the test sites. This procedure was later changed to using switching locomotives alone, because they could be scheduled easier, provided a more repeatable load, and allowed more load applications in a given day. The applied loads from the switchers could also be judged better, because the speeds were more controllable. Unfortunately, records of the amount of actual traffic tonnage passing over the test sections were not kept. However, because approximately 50% of the main line traffic was diverted onto the siding test section, it may be assumed that the siding recieved about 5 MGT per year,i.e., one-half of the single track total of 10 MGT.

3.0 QUASI-STATIC TRACK SYSTEM RESPONSE

Depending upon the nature of the ballast, subgrade and loading environment, geotextiles may perform in a highly site-specific manner. As mentioned earlier, there are four postulated mechanisms by which a geotextile is thought to influence track behavior in general: (1) reinforcement, (2) moisture transport, (3) filtration, and (4) separation. The instrumentation readings will be presented in Sections 3 and 4 of this report. In Section 7, the measurements will be discussed to determine if and how much any of the above mechanisms influenced behavior.

3.1 <u>Soil Moisture Measurements</u>

Laboratory moisture tests revealed that the natural subgrade was nearly saturated and the compacted layer of clayey loam was partially saturated. Soil moisture was measured to monitor the relative percentage ratio of pore water to soil solids (water content). Three methods were used to monitor the soil water content: (1) manual corings, (2) electrical resistance transducers (gauges), and (3) electrical capacitance transducers (gauges). Porewater pressures were also monitored using pneumatic transducers embedded within the subgrade.

Drainage in the test sections was dependent upon the topography and local soil properties. Figure 2 indicates the grade conditions for the overall test site. The steeper grade in Section 1 provided better drainage; however, this section also received runoff from Sections 2 and 3. Thus, various combinations of grade and watershed did not appear to favor any particular section.

Soiltest soil moisture gages (resistance type) were implanted near the surface of the subgrade (2 to 4 inches deep) in a line perpendicular to the rails. These gauges were located beneath the south edge of the tie, south rail, centerline of track, and the north rail, as shown in Figure 1. Figure 4 indicates the moisture variation at each location, as recorded by the resistance gauges in each section.

Ecotec capacitance soil moisture gages were also installed perpendicular to the rails, as indicated in Figure 1. Three gauges were placed one foot beneath the soil surface at the following locations: 2 feet south of the tie; south edge of the tie; and the centerline of the tie. The fourth gauge was located at the centerline of the tie, but was buried to a depth of 3 feet. The Ecotec soil moisture readings are shown in Figure 5 for each location in the six test sections.

The soil moisture contents obtained from actual soil corings are listed in Table 2. Soil samples were obtained every 6 inches, to a depth of 24 inches, at the middle of each test section. The water contents listed in Table 2 are the averages of these values. Figure 6 illustrates the variation of subgrade water content in the test sections over approximately one and one-half years. There is an apparent time lag between periods of heavy rain (see Figure 3) and maximum soil moisture. Figure 7 shows the difference between maximum and minimum soil moistures as obtained from the hand-cored samples.

Agreement among the various soil moisture measurement techniques appears to be lacking. Part of this may be explained on the basis of the variation of soil type with depth. However, the moisture data from the hand-cored samples was assumed to be more reliable than the data from the instrumentation.

3.2 <u>Pore Water Pressures</u>

Pore water pressures in the subgrade were monitored using pneumatic piezometers. The piezometers were implanted within the subgrade in each section in a plane perpedicular to the

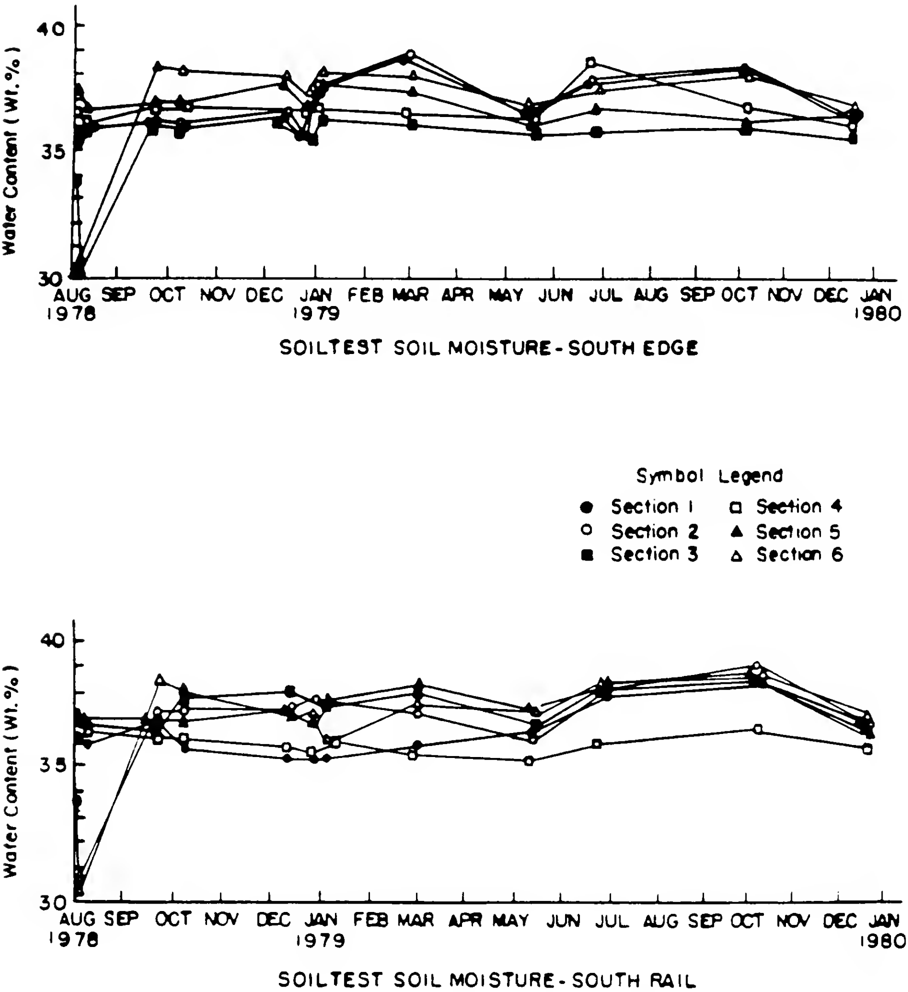


Figure 4a. Variations in Soiltest Moisture Gauge Readings With Time, for the South Edge and South Rail Locations in Test Sections 1-6.

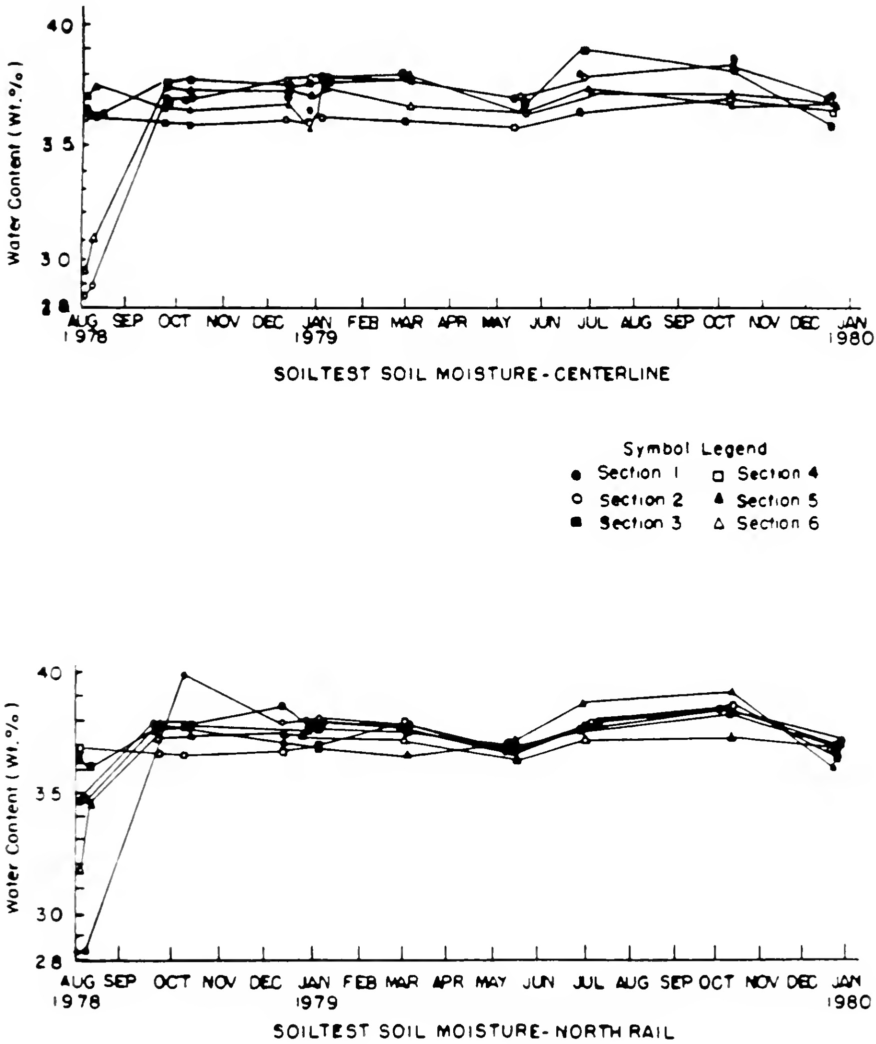
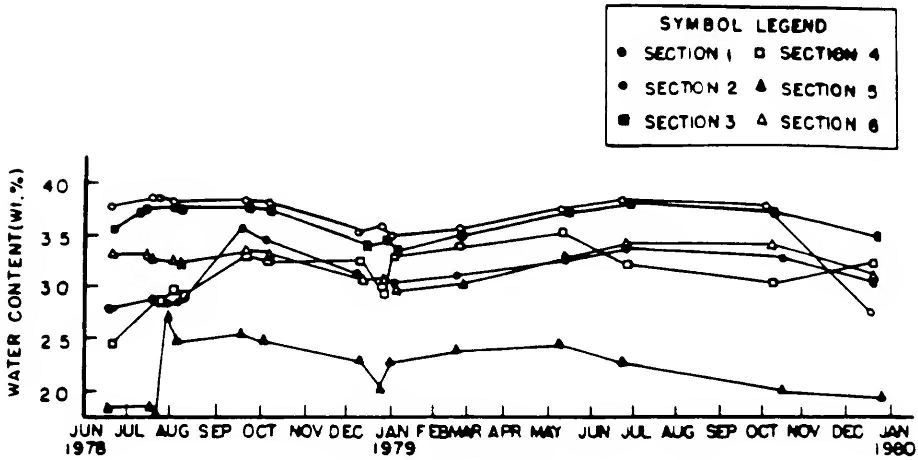
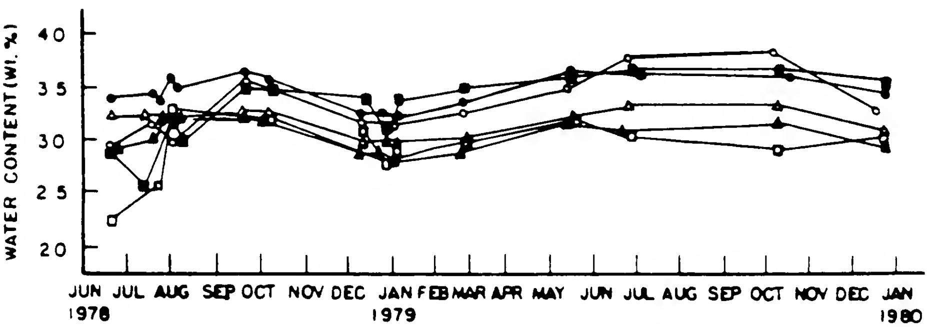


Figure 4b. Variations in Soiltest Moisture Gauge Readings With Time, for the Centerline and North Rail Locations in Test Sections 1-6.



ECOTEC SOIL MOISTURE - 2 FT. SOUTH



ECOTEC SOIL MOISTURE - SOUTH EDGE

Figure 5a. Variations in Ecotec Moisture Gauge Readings With Time, for the Two-Feet-South and South Edge Locations in Test in Test Sections 1-6.

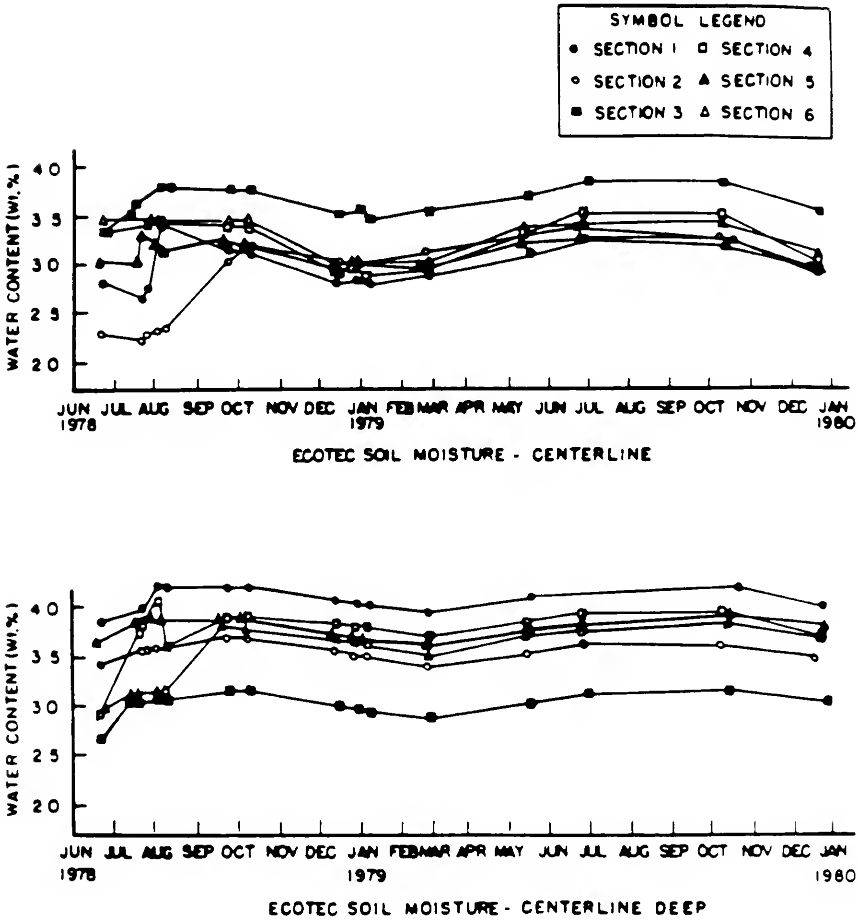


Figure 5b. Variations in Ecotec Moisture Gauge Readings With Time, for the Centerline and Centerline-Deep Locations in Test Sections 1-6.

Table 2

Seasonal Soil Water Content Variations in Test Sections 1-6. Values are Shown in Weight Percent.

Test Dates

South Rail

Test Section	7/78	10/78	12/78	3/79	5/79	6/79	10/79	12/79	3/80
1	26	27	26	23	27	24	28	32	29
2	26	36	33	30	36	32	37	37	34
3	25	32	37	29	31	27	34	36	36
4	20	30	29	30	29	22	27	37	27
5	25	25	27	22	24	19	23	30	28
6	22	22	--	15	--	19	23	25	--

Centerline of Siding

Test Section	7/78	10/78	12/78	3/79	5/79	6/79	10/79	12/79	3/80
1	--	--	--	24	28	--	--	34	
2	--	--	--	26	33	--	--	37	
3	--	--	--	27	31	--	--	32	
4	--	--	--	30	28	--	--	31	
5	--	21	21	19	28	--	--	25	
6	--	--	--	17	20	--	--	--	

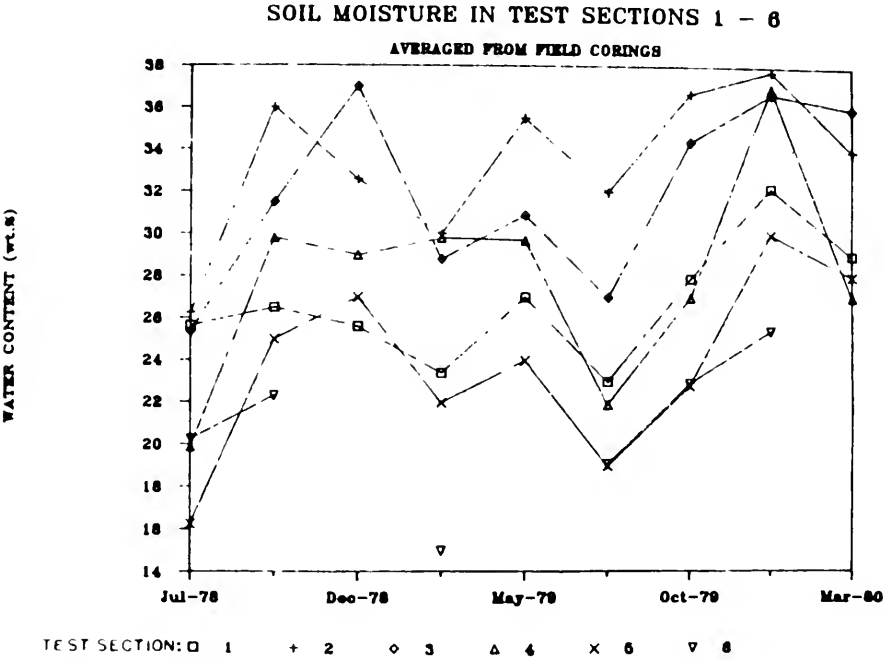


Figure 6. Variations in Average Soil Water Content With Time, in Test Sections 1-6.

rails. Shallow piezometers were placed 15 inches beneath the finished subgrade at locations below the south edge of the ties, the south rails, and the centerline of the siding. The soil strata profiles presented in Figures 13 through 18, indicate that the 15-inch depth of insertion was sufficient to place the piezometers beneath the compacted fill layer. An additional piezometer was placed to a depth of 4 feet beneath the finished subgrade at the centerline of each test section. Each piezometer was built to measure both the positive pore water pressures that would result from a hydrostatic head, and the negative pore water pressures, associated with capillary rise, surface desiccation, and compacted soils. The data obtained from the piezometers are presented in Figure 8.

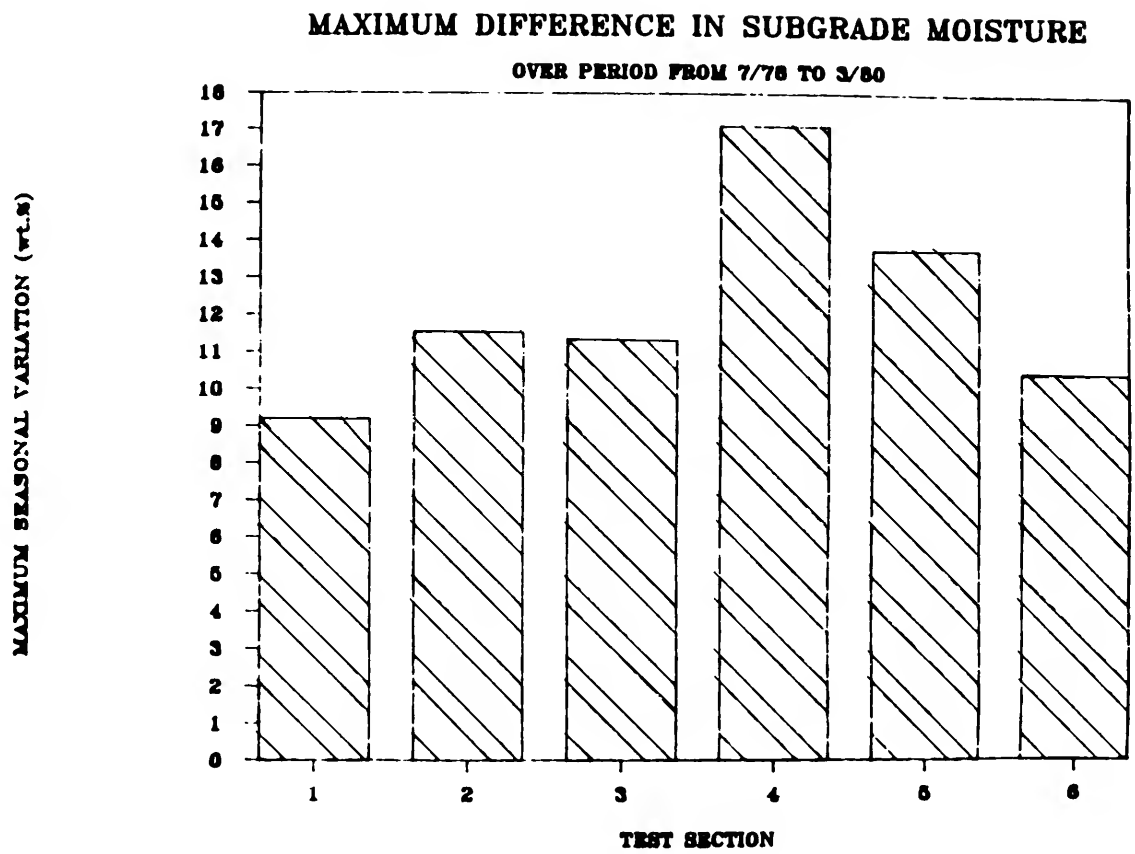
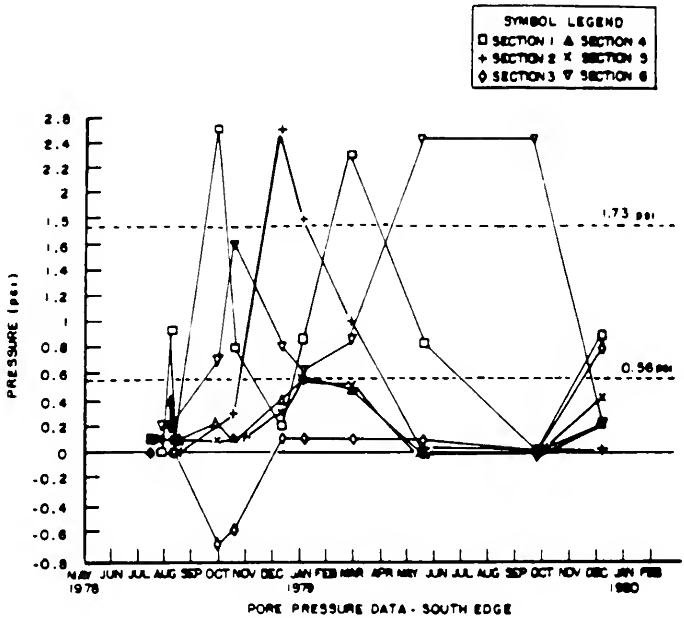


Figure 7. Maximum Seasonal Variations in Soil Moisture Content from July, 1978 to March, 1980, for Test Sections 1-6.



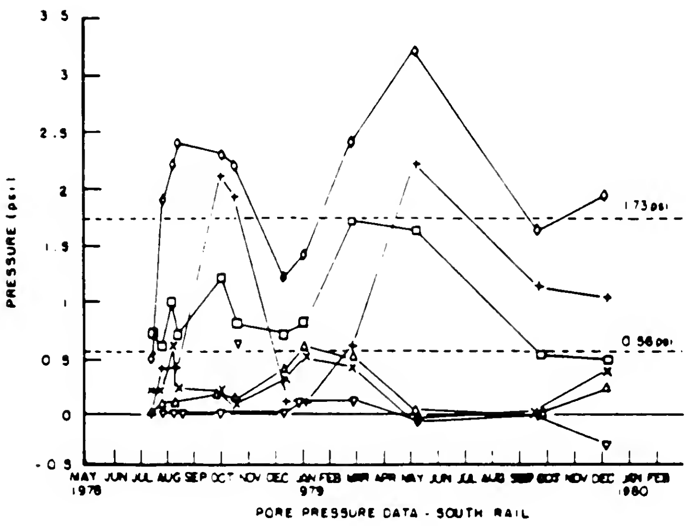


Figure 8a. Variations in Pore Water Pressure With Time, for the South Edge and South Rail Locations in Test Sections 1-6.

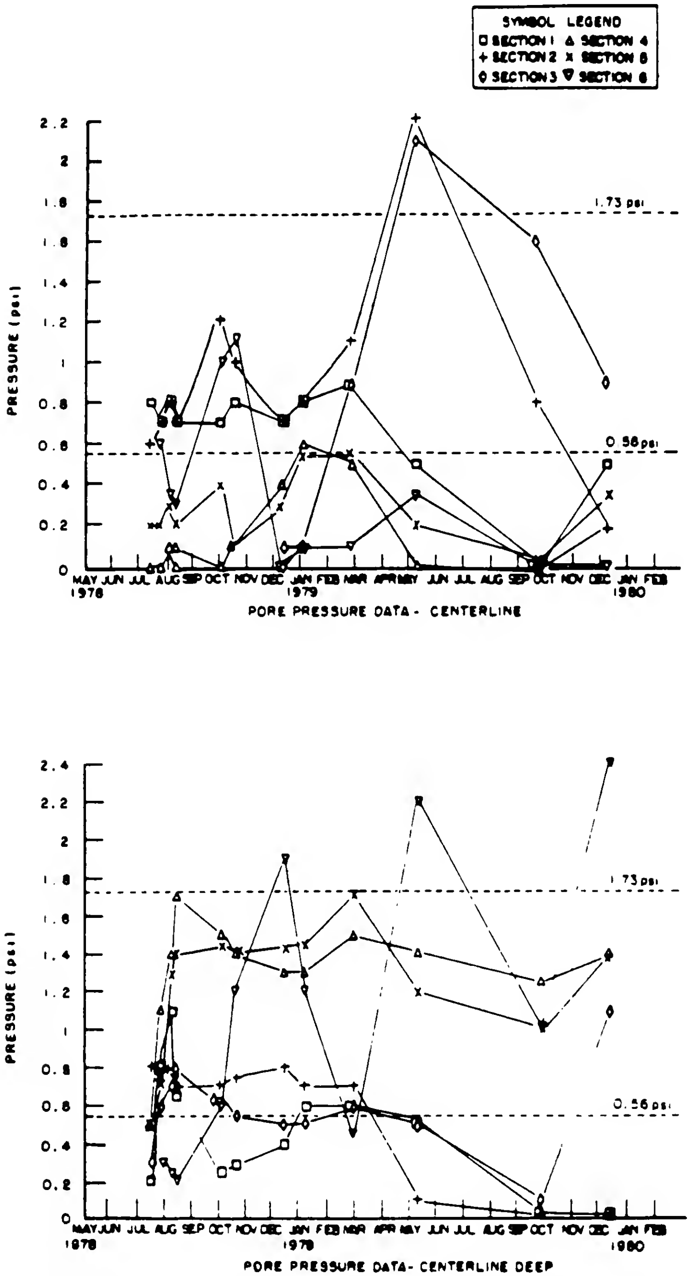


Figure 8b. Variations in Pore Water Pressure With Time for the Centerline and Centerline-Deep Locations in Test Sections 1-6.

Positive pore water pressures can be generated by static surcharge loads, applied to a saturated soil layer by "squeezing" (consolidating) water from the soil, or by hydrostatic pressures resulting from the water table being located higher than the piezometer. Instantaneous rail loads will generate transient positive pore water pressures in the saturated clays beneath the fill, but these pressures should dissipate rapidly. Piezometer readings were not taken while the rails were loaded, therefore the measured pore water pressures should not reflect traffic-induced transient pore water pressures.

Maximum positive pore water pressures would occur if the water table is assumed to be at the surface of the subgrade. Thus, the maximum positive pore water pressures measured at Caldwell should be 0.54 psi for the shallow piezometers and 1.73 psi for the deep piezometers, based on the depth below the water table. The field excavations at Caldwell did not visually indicate that the fill layer on the surface was saturated. The pore water pressures in test Sections 4 and 5 (control section) displayed climatic trends that were consistent with the anticipated pore water response; during the wet winter and spring, the pore water pressures rose and approached the pressure limits defined by the surface water table model. Pore water pressures in excess of 0.54 psi were measured by the shallow piezometers at Sites 1, 2, 3, and 6. Pressures approaching 3.6 psi, however, were also measured by shallow sensors, which conflicts with the maximum pore water pressure model developed at the beginning of this section.

Excess positive pore water pressures could lead to reduced subgrade strengths and increased settlements, caused by water flowing out of the subgrade to reduce the pore water pressures (consolidation). Sections 1, 2, and 6 did not experience significant settlements and certainly did not appear to be showing any signs of weak or failing subgrades. The greatest pore pressure was recorded in Section 3, which did eventually fail. However, the excess pressures could be related to gauge damage, or might have been generated by a hydraulic link between the gauge and free water in the elevated soil embankment south of the track.

3.3 Track System Geometry

Changes in track geometry can occur in response to the following mechanisms: (1) permanent (plastic) settlements caused by cyclic service loads, (2) shrinkage or swelling of the soil, resulting from moisture content changes in the subgrade, and (3) consolidation settlements caused by a change in the static vertical effective stress in the subgrade. Rather than try to determine the relative contribution of each of these, the decision was made to measure the overall track geometry by surveying the top-of-rail (TOR) profile at certain station numbers along the siding.

The TOR survey was performed on both rails at intervals of 50 feet within each test section. Relative changes in the TOR profile were less than +/- 0.50 inch. Significant TOR changes were observed only around the centerline of Section 3, as shown in Figure 9. The TOR surveys indicated that a drop of 0.2 ft occurred between the initial (June, 1978) and final surveys (February, 1980).

3.4 Subgrade Geometry

Subgrade geometry was monitored by using data from the

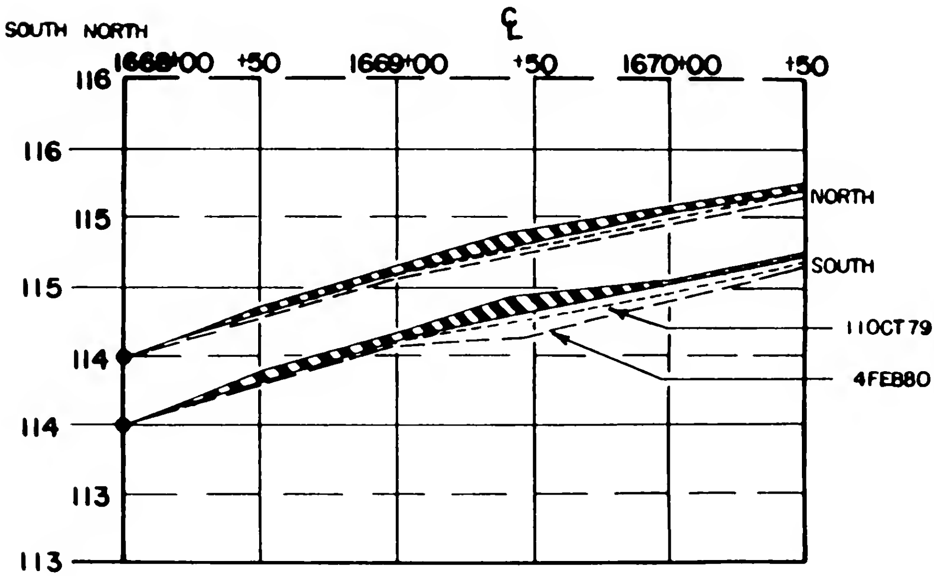


Figure 9. Relative Track Geometry Variations With Time in Test Section 3.

profile tubes, static extensometers, Bison inductance sensors and track excavations. However, the inductance sensors did not provide any reliable measurements, due to failure of the read-out device. Subgrade geometry changes that were measured using the profile systems were inconclusive. The profile transducer could provide no greater accuracy than +/- 1.0 inch in service, and this accuracy wss within the range of the actual TOR movements observed in all test sections.

Static vertical extensometer readings were recorded to monitor the vertical movement of the soil-ballast interface with respect to a point 10 feet below. The static extensometer readings are shown in Figure 10. All of the curves shown a consistent trend in the rise and fall of this interface.

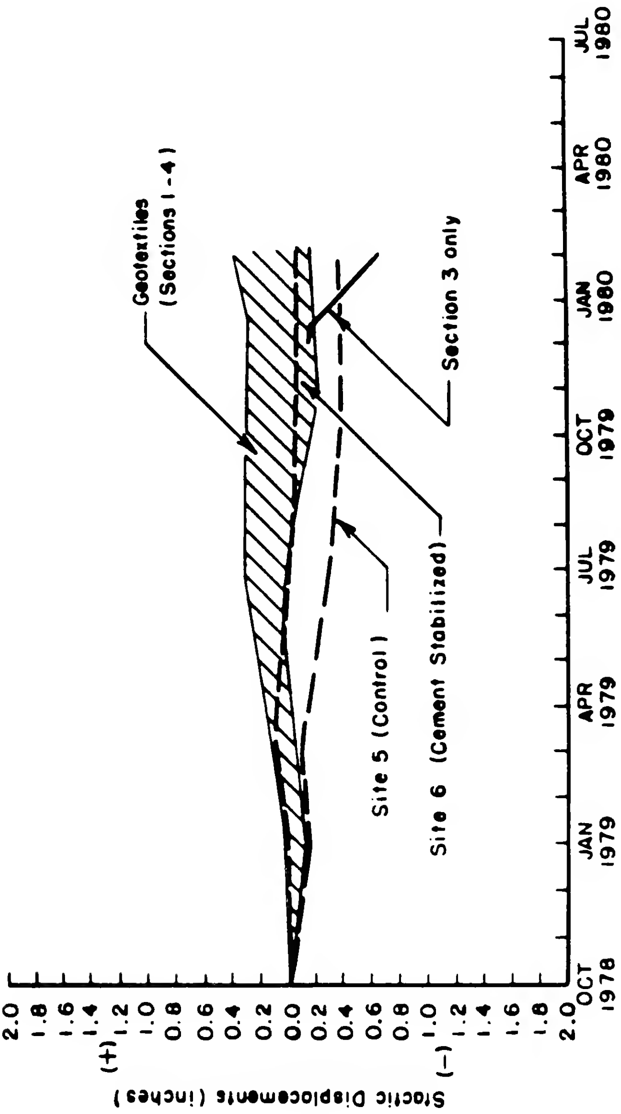


Figure 10. Extensometer Data Showing Static Soil Displacement Variations With Time in Test Sections 1-6.

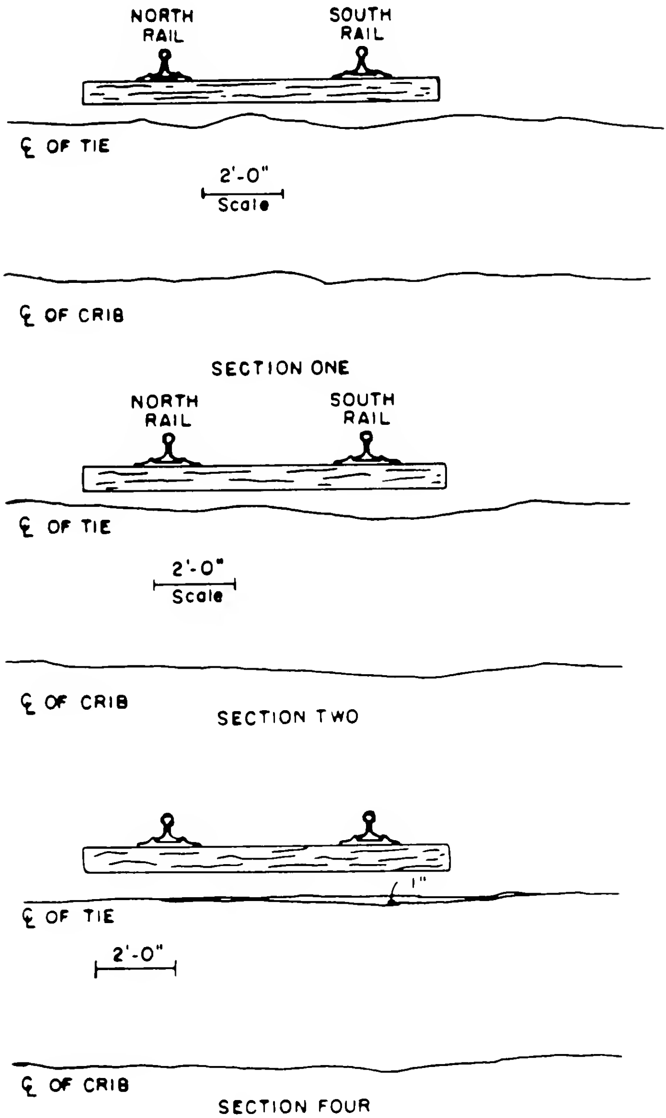


Figure 11. Transverse Subgrade Profiles in Test Sections 1, 2, and 4.

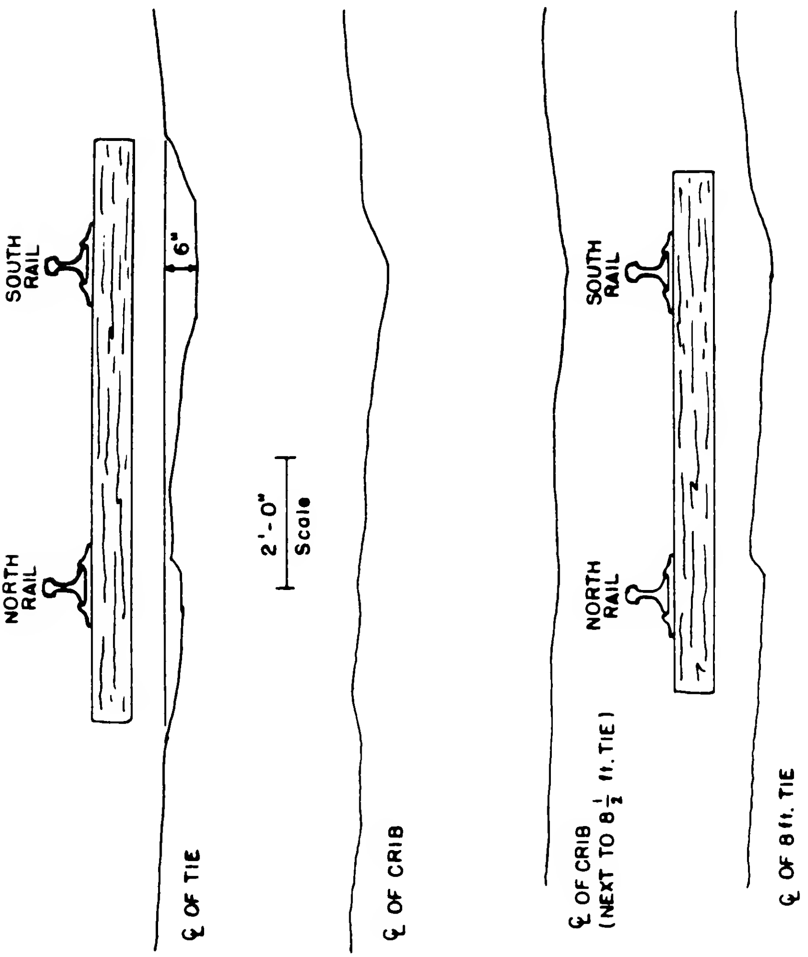


Figure 12. Transverse Subgrade Profiles at Four Locations in Test Section 3.

Section 5, the control section, clearly experienced greater vertical settlements than the remaining sections. Note also that the vertical movement of Section 3 begun to accelerate rapidly during December, 1979. The failure of Section 3 occurred in January, 1980, as noted in Figure 10.

Track excavations were made in each of the fabric sections to observe the transverse subgrade profile under both a tie and a crib. Elevations were taken at the top of the fabric in each excavation before it was removed to reveal the subgrade. The contours for Sections 1, 2, and 4 are shown in Figure 11. Of particular interest are the large subgrade displacements indicated for Section 3, as shown in Figure 12. The excavation in Section 3 was made in an area where the TOR profile had indicated large settlements. This provided further evidence of the soil-related failure of Section 3. The subgrade profiles from all of the geotextile sections showed a depression of the subgrade below the tie-rail Seats. The depth of this depression ranged from less than one inch in Section 4 to more than six inches in Section 3.

In order to investigate further the conditions associated with the fabric sections, shallow trenches were excavated on the south side of the siding, to obtain the engineering properties of the near-surface subgrade. Hand shovels were used to dig to a depth of between 12 and 18 inches. Significant soil profiles were mapped, and penetrometer unconfined-compression measurements and water contents were obtained.

The near-surface subgrade profiles, shown in Figures 13 through 18, all show the compacted clayey loam. This compacted soil has significantly greater strength and lower plasticity than the underlying in-situ soil.

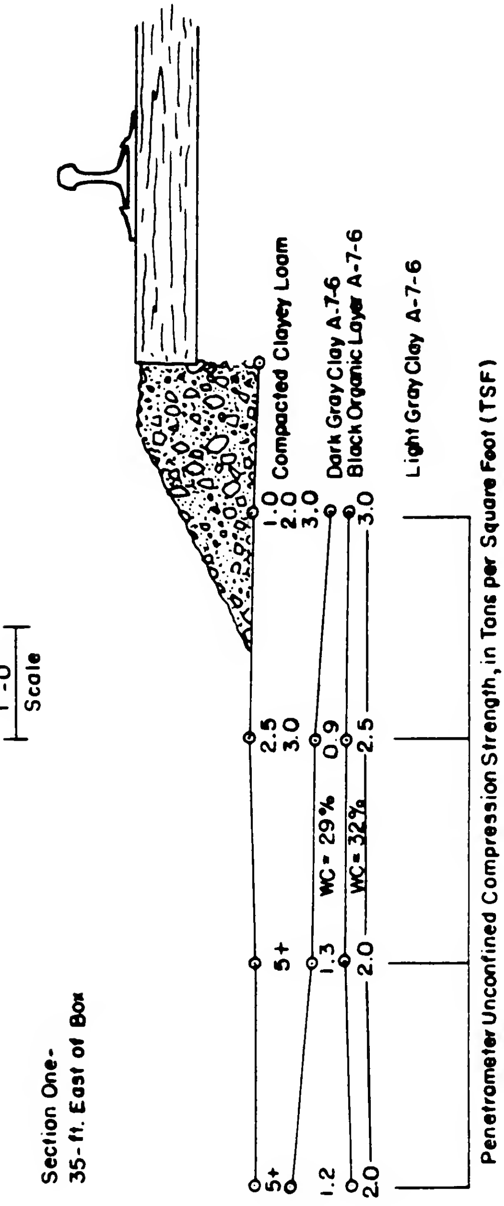


Figure 13. Near-Surface Subgrade Characteristics in Test Section 1.

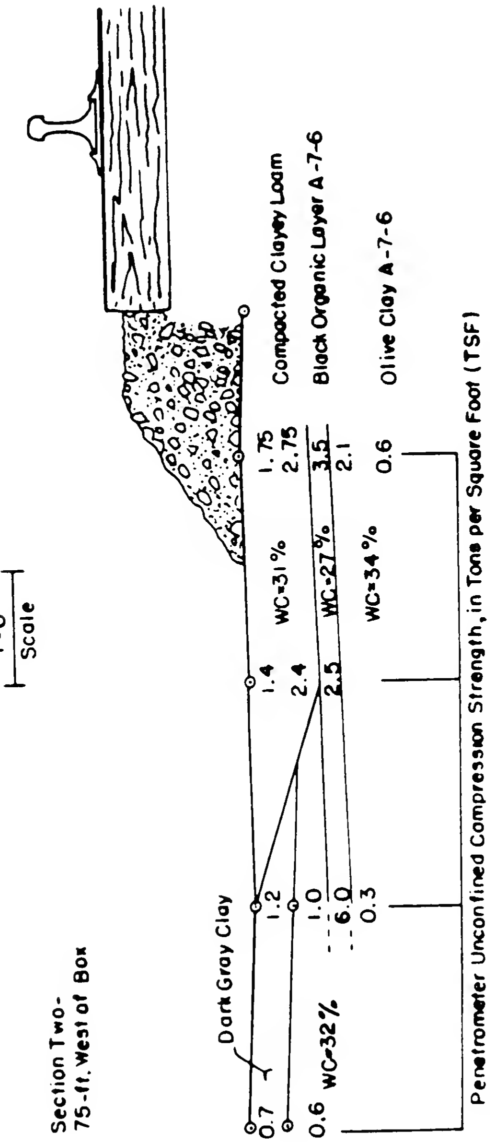


Figure 14. Near-Surface Subgrade Characteristics in Test Section 2.

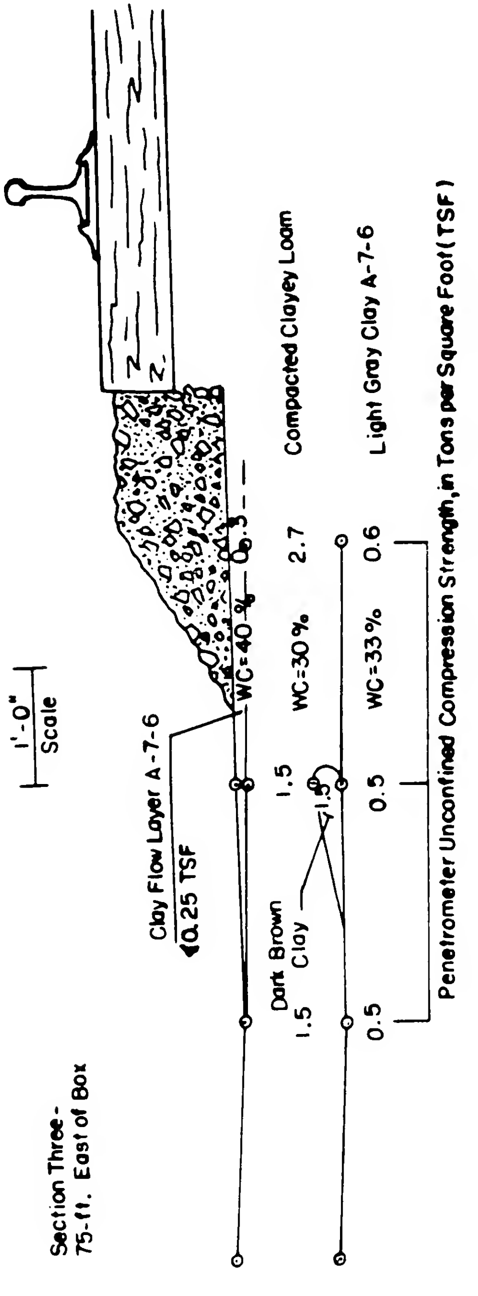


Figure 15. Near-Surface Subgrade Characteristics at a Location 75 Feet East of the Centerline of Test Section 3.

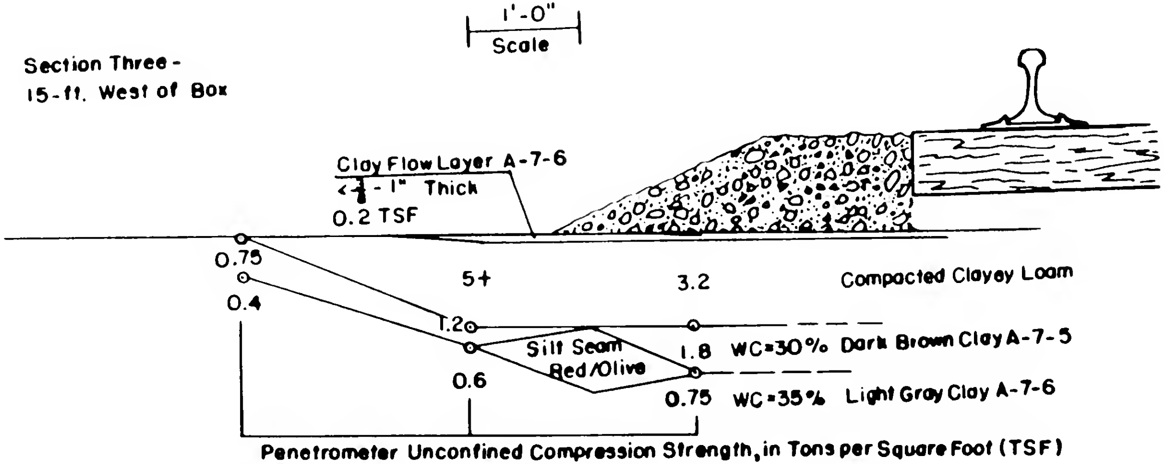


Figure 16. Near-Surface Subgrade Characteristics at a Location 15 Feet West of the Centerline of Test Section 3.

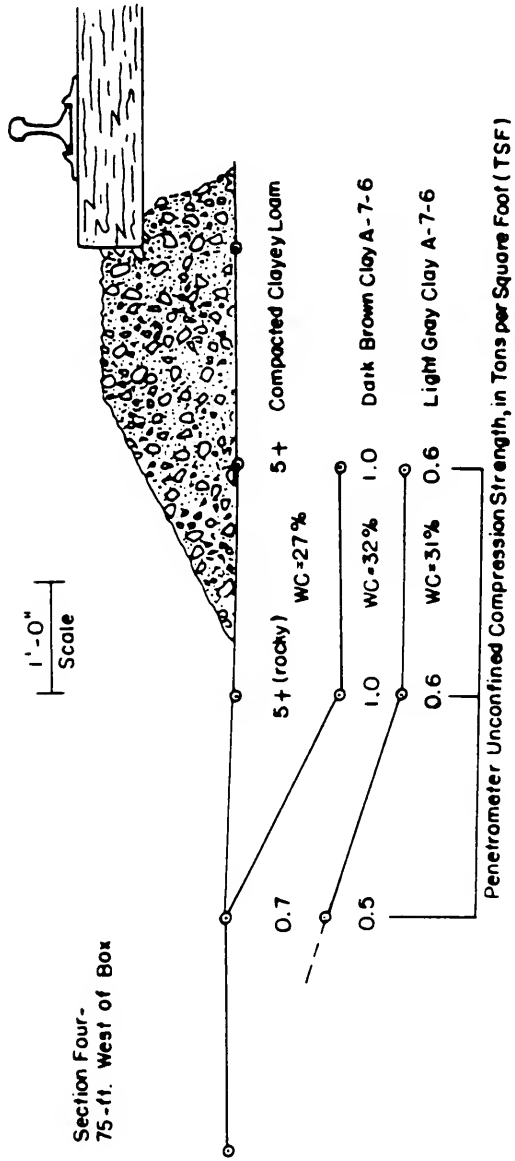


Figure 17. Near-Surface Subgrade Characteristics in Test Section 4.

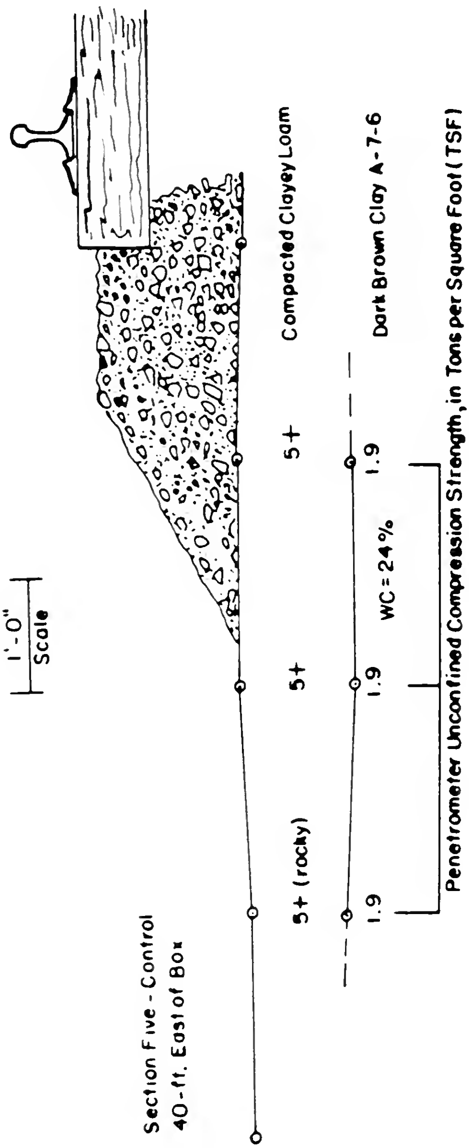


Figure 18. Near-Surface Subgrade Characteristics in Test Section 5.

Sections 1 and 2 had nearly the same profile, approximately 8 to 9 inches of compacted clay, overlying a dark grey or brown clay, under which was a light grey clay layer. Because of the large settlements observed, two excavations were made in Section 3. Figures 15 and 16 show the same 8 to 9 inches of compacted fill in Section 3, as in Sections 1 and 2. The dark brown clay found in the two previous sections was missing in one of the excavations made in Section 3, because it was removed to achieve the desired design elevation during the siding construction.

The most significant finding made at Site 3 was a layer of weak clay slurry, located just under the fabric in both excavations. The penetrometer unconfined compression strength of the clay slurry was less than 0.25 tons per square feet (TSF). The layer appeared to be extruding from beneath the fabric. The existence of this layer pointed to a near-surface soil failure as contributing to the excessive settlement in Section 3. The low permeability of the fabric appeared to be the cause of the slurry formation. More discussion of this problem location will follow in a later section of this report.

Nearly one foot of compacted clay overlay the layers of dark brown and light grey clays in Section 4. In Section 5, the light grey clay layer apparently dipped and was no longer located within the near surface subgrade profile.

From the excavations and some of the soil borings, a complete profile of the most significant track system layers was drawn, as shown in Figure 19. This profile shows the uniform layer of compacted clayey loam under the ballast. The ballast depth was reasonably uniform, with the exception of Section 3 where it decreased from 8 to 6 inches. The subgrade soils have been simplified in Figure 19 to the dark brown clay immediately

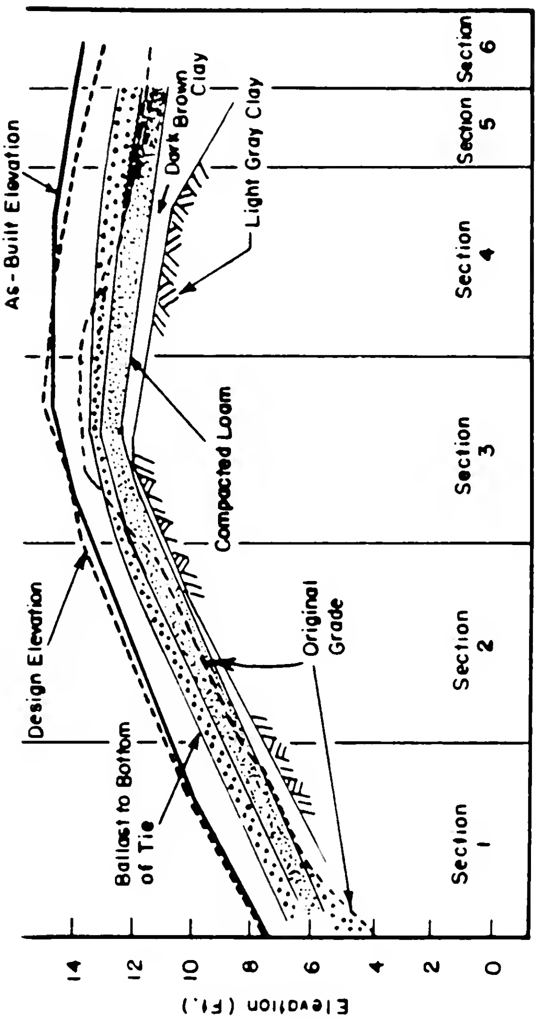


Figure 19. Significant Ballast and Subgrade Layer Profiles in Test Sections 1-6.

below the fill and a foundation of light grey clay. The abrupt narrowing of the dark brown clay layer in Section 3 was due to grading during construction.

4.0 DYNAMIC TRACK SYSTEM RESPONSE

4.1 Subgrade Response

4.1.1 Earth Pressures

The transducers for measuring vertical earth pressures were installed 3-4 inches below the top of the subgrade. Figures 20 and 21 show the transverse and longitudinal layouts of the transducers in the soil. The earth pressure measurements shown in these figures were obtained by selecting the maximum pressure registered by each transducer during each locomotive pass. These maximum pressures were generated under the wheel loads of switcher locomotives traveling at velocities ranging from 2 and to 50 mph. Because the maximum pressures varied somewhat with locomotive speed (although with no definite trend), the average of the maximum pressures for the various speeds was calcluated and plotted in Figures 20 and 21. The resulting variation of maximum pressures with locomotive speed was small in most cases.

The transverse and longitudinal earth pressure measurements showed approximately the same pressure profiles for each site. No significant differences could be observed between the pressure profiles observed in the fabric sections and those in the control section. It is interesting to note that the maximum subgrade pressures were measured beneath the cement-stabilized section.

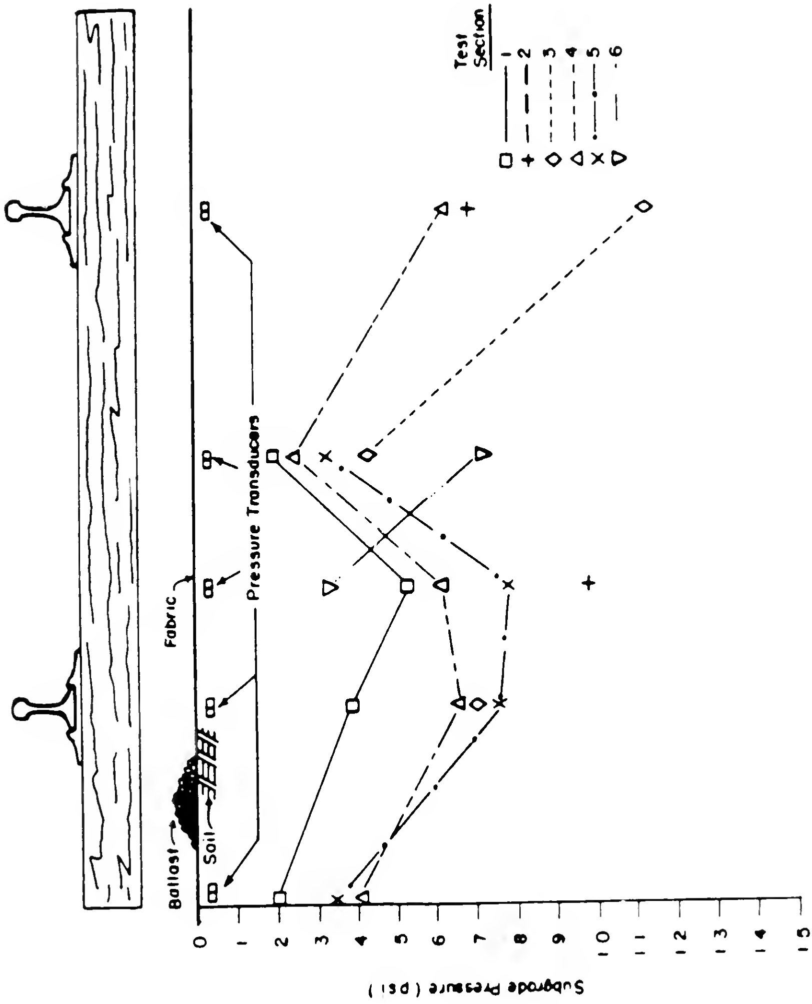


Figure 20. Subgrade Pressures Under One Tie in Each of Test Sections 1-6.

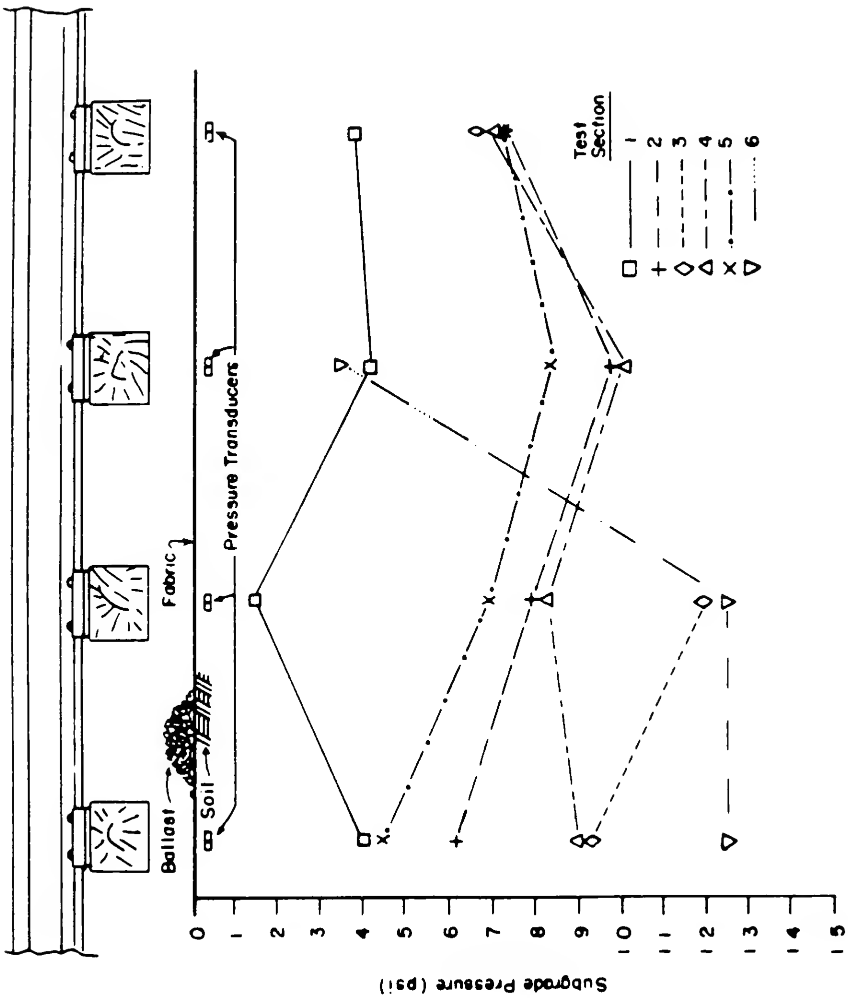


Figure 21. Subgrade Pressures Under Four Ties in Each of Test Sections 1-6.

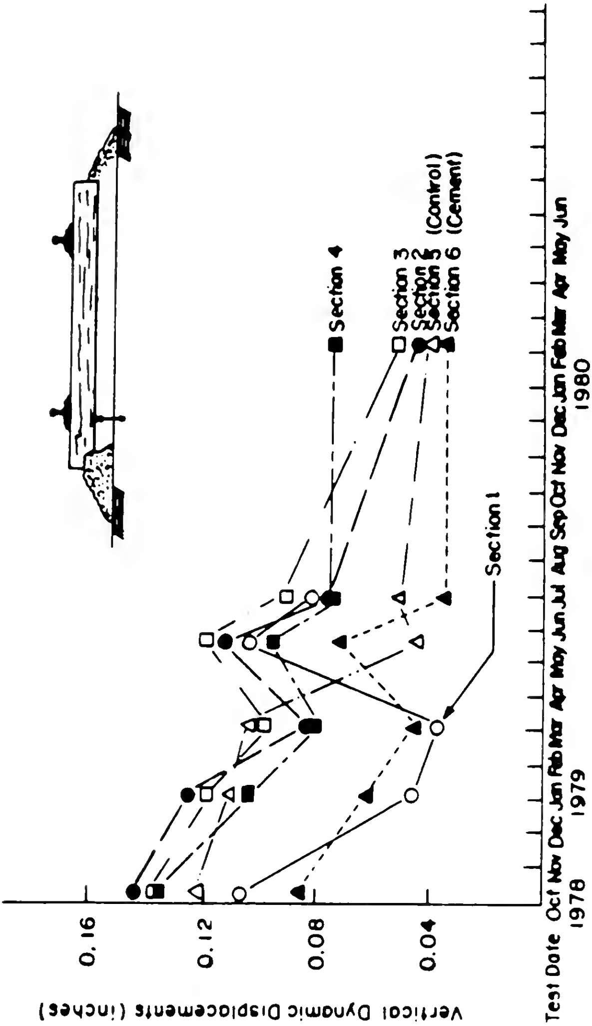


Figure 22. Variations in Mean Values of Elastic Deformation Under Load at the Ballast/Subgrade Interface With Time, for Test Sections 1-6.

4.1.2 Elastic Subgrade Deformations

Measurements of elastic subgrade deformations under load were obtained using three extensometers per section, which were installed under the rail-tie seats. The mean values obtained under loading are plotted in Figure 22 for the respective test dates. The elastic deformations measured in Sections 2, 3, 4, and 6 showed the same climatic variations, with Section 6 having consistently smaller amplitudes. General weather data obtained from Caldwell Texas, and shown in Figure 3, clearly illustrates that March through June were months that had significant amounts of rainfall, which explains the increase in dynamic deflections in all sections but Section 5.

The anomalous behavior of Section 5 during the wet season was shown by decreasing elastic deformation, while the other sections were experiencing increasing deformations. Section 1 also had anomalous behavior, as evidenced by the wide range in deformation with the seasons. The soil moisture content data did not indicate that the soil in Section 1 experienced greater variation in moisture content; in fact, the moisture content in Section 1 was the most uniform during this period.

4.2 <u>Superstructural Response</u>

4.2.1 <u>Tie Plate Loads</u>

The portion of the wheel load that was distributed to the single tie over which the wheel was located was measured at one tie in each section, using a load cell tie plate. The load cell tie plates were installed just prior to the time of measurement and then replaced with ordinary tie plates after the testing was completed.

The maximum tie plate loadings for all six sections were 19, 18, 14, 10, 11, and 20 kips, respectively. Sections 1, 2, and 6 appeared to have the largest loads. However, tie loads can be variable from one tie to the next, even in new construction. Tests elsewhere have shown that the percentage of wheel load taken by the tie directly under a particular wheel may vary between 20% and 50% [1],* depending upon the tie support conditions and rail stiffness. In these tests, the range of the tie loads divided by the wheel loads (about 33 kips) for all six sections were between 30% and 60%. Because the test results were within the natural variations of the tie load spectrum, and because only one tie per section was instrumented, data from the instrumented tie plates could not be used to explain the observed differences in test section behavior.

4.2.2 Tie Strains

The tie strains were measured by gauges attached to the top of one tie in each test section, as shown in Figure 23. This enabled the dynamic bending strains in the longitudinal plane of a tie in each section to be monitored. It appeared, however, that the ties in Sections 5 and 6 were center bound, whereas the fabric section ties were strained more uniformly. However, as mentioned previously, the tie support conditions, and therefore the bending, could vary considerably from tie to tie. Therefore, any differences in section response could not be confirmed from these data.

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* Numbers in Square brackets indicate the References, listed in Section 9.0 of this report.

4.2.3 Dynamic Vertical Rail Deflections

The rail deflections under load were measured at one location per test section at various locomotive speeds. Unfortunately, a large amount of "noise" in these data aquisition system channels made interpretation of the data

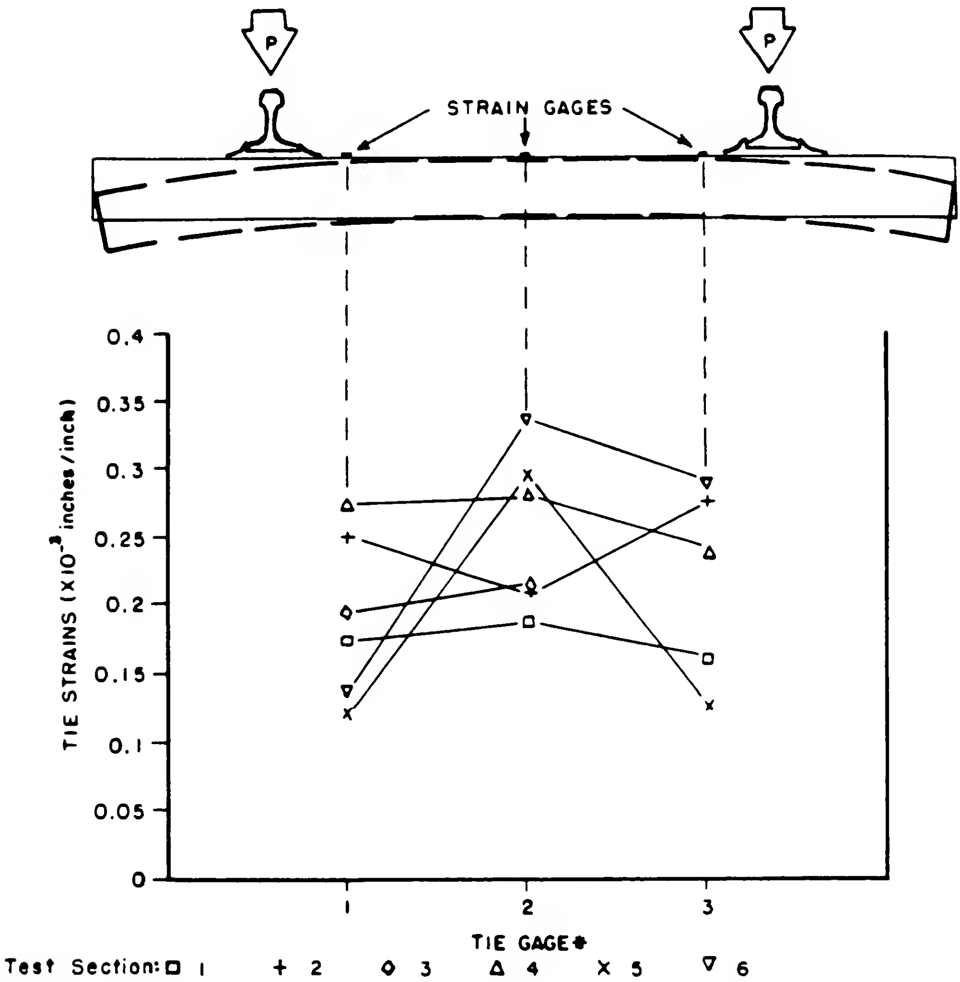

Figure 23. Measured Bending Strains in an Instrumented Cross Tie, in Each of Test Sections 1-6.

extremely difficult. It was, however, possible to "piece together" good data for a few sections from a test performed in March, 1979 and compare it with good data from the other sections obtained during a test in May, 1979. However, this would have been misleading, because of the seasonal dependency of the subgrade dynamic deformations in each section, as illustrated in Figure 22. Therefore, no data from this test can be presented.

4.2.4 Dynamic Rail Stresses

Rail stresses under load were measured under the rail head and on the top of the rail base. The range of values that were measured is shown in Figure 24. Unfortunately, the gauges in Section 6 were not functional. The range of rail stresses for each section were practically the same, and therefore, sectional differences were not evident.

5.0 BALLAST CONTAMINATION

Filtration and separation are two of the attributes most commonly associated with the use of geotextiles in railroad applications. To assess the performance of the fabric sections with respect to these two characteristics, samples of ballast, soil, and fabric were taken from the field for laboratory analysis.

Differentiating the subgrade fines from fines of other sources, e.g., from ballast abrasion, windblown, etc. was essential to evaluating the performance of the various geotextiles. Section 6, the cement-stabilized section, played a key role in this investigation, because it contained fines from all sources other than those associated with the subgrade.

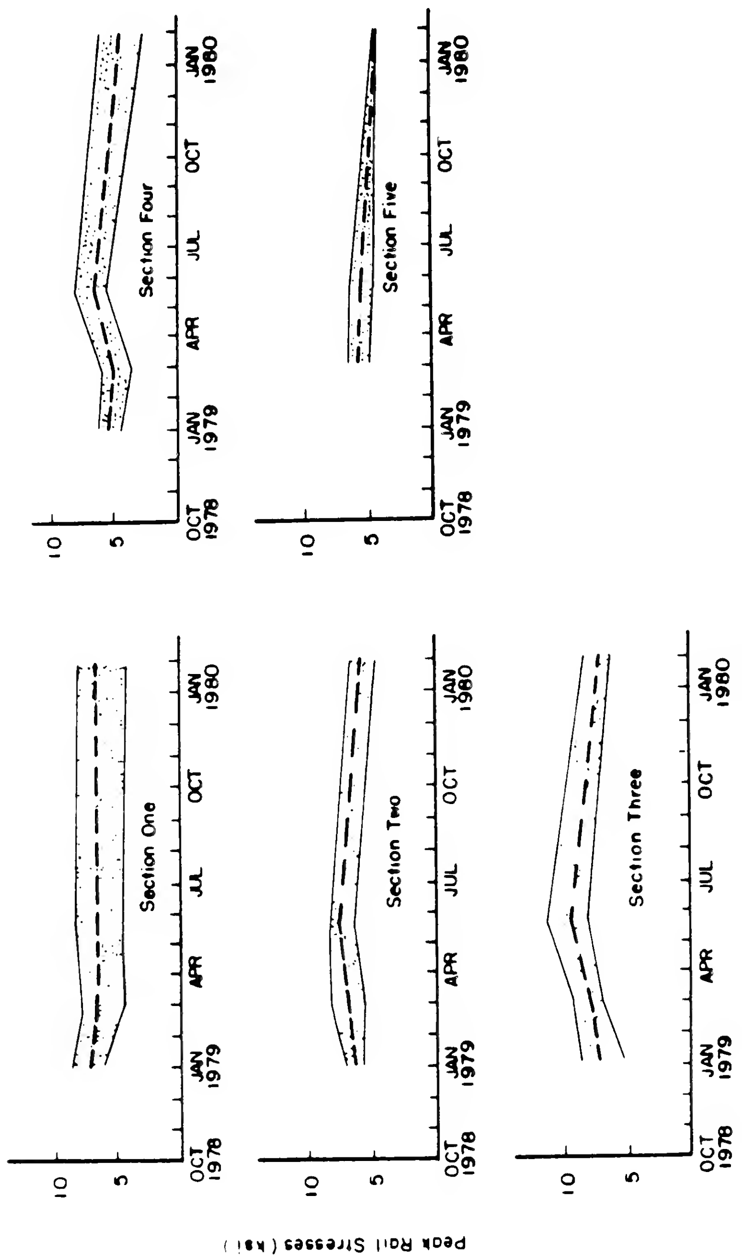

Figure 24. Variations in Dynamic Rail Stresses With Time, in Test Sections 1-5.

Assuming reasonably uniform ballast and surface conditions, the contaminating fines measured in Section 6 should represent a control for the other test sections.

Ballast samples were taken at uniform increments of depth below the top of the ties in Sections 1 through 6. Additional samples were obtained from the top of, and beneath, the fabric in Sections 1 through 4. Samples were also taken at the soil-ballast interface, and at the top of the cement at Sections 5 and 6, respectively. Samples were obtained from holes dug by hand in the ballast. A water spray mist was used to prevent the fines from being displaced due to the sampling disturbance. Approximately 700 to 800 grams of ballast were taken at each depth.

The contamination, as quantified by measuring the amount of fines that passed through a #200 sieve (0.074 mm), consisted of both silt and clay-sized particles, and were assumed to be representative of the ballast contamination.

Mean values were established for the percentage of contamination versus depth data from each test section, and are presented in Figure 25. In the upper 12 inches of ballast, only Sections 3 and 5 had contamination in excess of that measured in Section 6 (the "control" section). Note the contamination of the ballast just above the fabric; Section 5, with no fabric, had significantly more contamination than the remaining sections, and only fabric Sections 3 and 4 had greater contamination than Section 6.

In addition to the amount of contamination, laboratory hydrometer analyses were performed to measure the percentage of clay particles in the contaminant fines. Clay particles in the contaminant could originate only as wind-blown particles or in

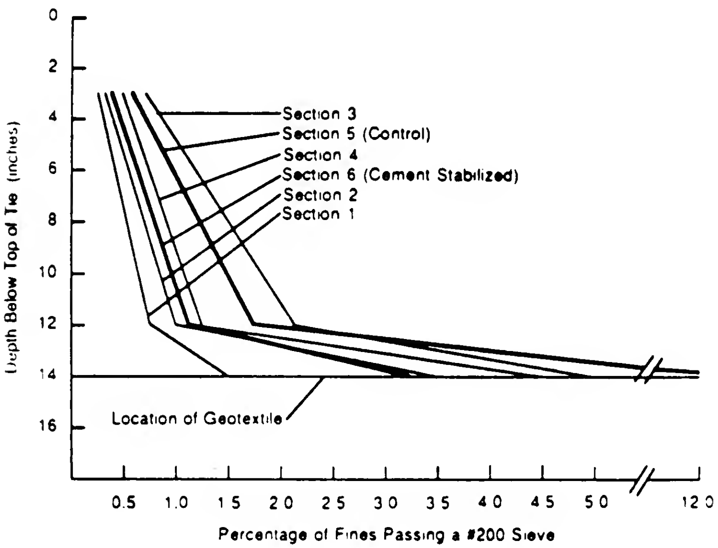

Figure 25. Percentage of Fines Passing a #200 Sieve Versus Sampling Depth in Test Sections 1-6.

the subgrade. Crushing and abrasion of the ballast would produce coarser silt-sized particles. The subgrade beneath the track consisted of both clay and silt-sized particles; therefore, the presence of excessive amounts of clay fines would indicate a filtering of the silts by the fabrics, as the fines tried to pass through the fabric.

Statistical data giving the percentage of clay-sized particles within the ballast fines are presented in Table 3. Using Section 6 as the control, it appears that the fabric sections received most of their additional contamination in the form of clay particles. This substantiated the filtering capabilities of the fabrics with respect to silt-sized particles. Section 5 exhibited a significantly lower percentage of clay within its ballast fines, indicating that large quantities of subgrade silts in addition to the clay, were moving into the ballast.

The absolute quantities of clay-sized particles present within the ballast in each test section are shown as a function of the total ballast sample weight in Figures 26 and 27. It appears that the percentage of clay in most sections was relatively small. Percentages less than 4% or 5% are normally considered to be negligible, in that they will not influence the ballast performance. However, Sections 3 and 5 had high clay percentages just above the subgrade interface, which were more than double the percentages in any other section. These clay percentages were high enough to contribute to a degredation of the engineering properties of the ballast.

It appears that the use of fabrics can control the pumping of silt-sized particles into the ballast. Fabrics will, however, allow a small amount of clay to pump into the ballast. This amount of clay will, however, be significantly smaller than would have occured if no fabric had been used.

Table 3

Mean Values and Standard Deviations for Measured Clay Percentages in Test Sections 1-6.

Test Section	Mean Value	Standard Deviation
1	50.3%	18.7
2	45.7	12.6
3	43.6	23.5
4	40.6	16.9
5 (Control)	32.6	5.1
6 (Cement)	25.2	19.9

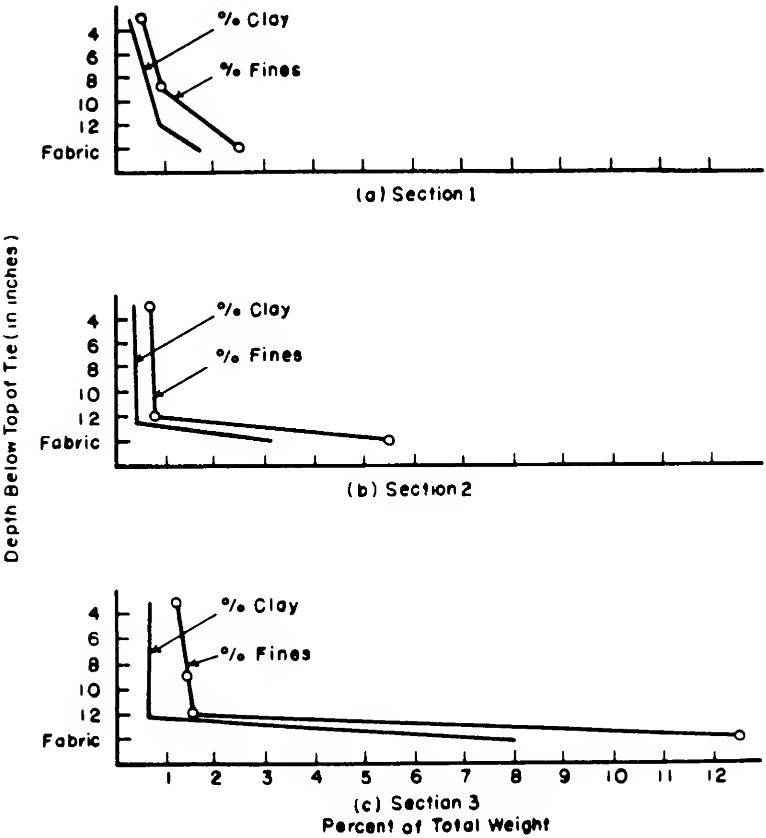

Figure 26. Percentage of Clay in Total Ballast Weight Versus Sampling Depth in Test Sections 1-3.

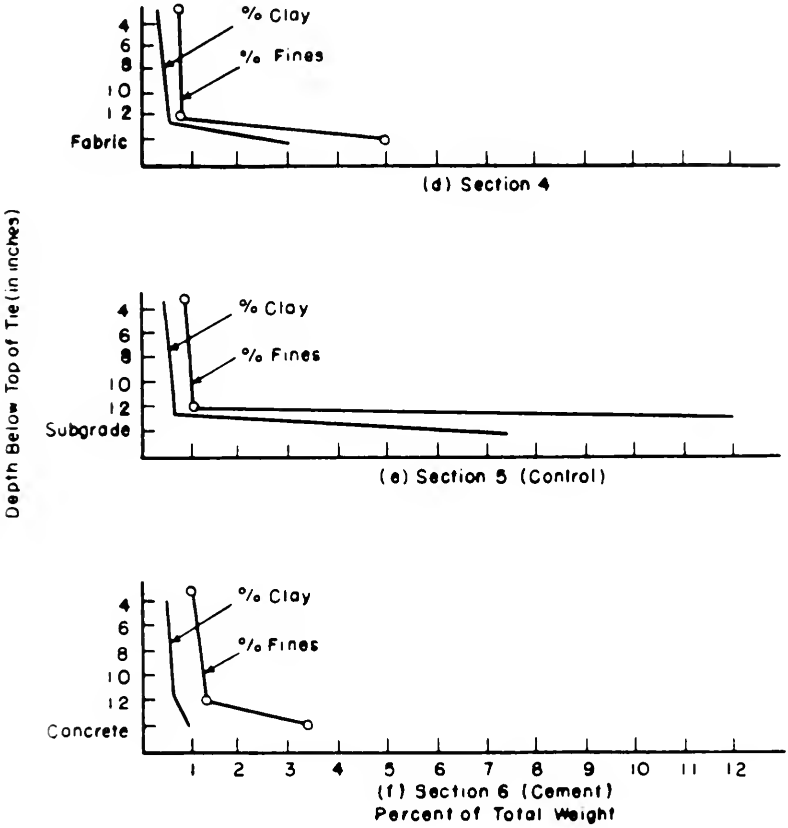

Figure 27. Percentage of Clay in Total Ballast Weight Versus Sampling Depth in Test Sections 4-6.

6.0 PROPERTIES OF RECOVERED GEOTEXTILES

After 17 months of service, several ties were removed and the ballast excavated, so that samples of fabric could be taken from each test section. The fabric samples were taken to a laboratory and tested for their permeability, both in-plane and normal to the fabric. Also, the strength in tension, as measured by the Grab Tensile Strength test, was determined.

Figures 28 through 30 illustrate the measured decrease in fabric permeabilities when tested in the soiled condition after removal from the field. As shown in Figure 28, the in-plane permeability of the fabric samples after 17 months in track had decreased by as much as a factor of 100. The fabric in Section 1 retained the greatest percentage of its initial normal and in-plane permeability. The test performed on the fabric from Section 3 appeared to show a gain in permeability in the field, however, this test was reported by the technician to be in error. The fabric in Section 3 is known to have clogged more severely in the field than any of the other fabrics.

A combination of visual and microscopic inspections revealed that all of the fabrics had soil particles in the voids of the fibers and on the fabric surfaces. Fabric 1 had the least amount of soil in the fibers, while the other three fabrics had a greater (approximately equal to each other) degree of soil particles in them. These obervations confirmed the laboratory permeability results.

The tests that were conducted to determine the permeability normal to the plane of the fabric again showed the fabric from Section 1 to have the smallest percentage decrease (see Figure 29). Even with permeability decreases on the order of 100, the soiled fabric permeability was still much greater than that of the soil itself.

It appears desirable to permit a certain amount of clay pass to into and through the fabric, while the silt is retained in the surrounding soil. If some clay fines are not allowed to pass into the fabric, they are retained just under the fabric and, after time, may form a very weak soil layer. The behavior of pore water pressure at the soil-fabric interface is crucial

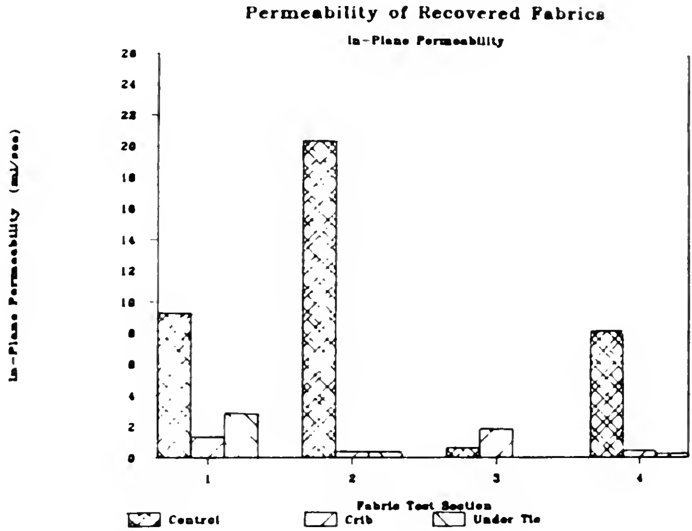

Figure 28. In-Plane Permeability of Geotextiles Recovered From the Field and Tested at a Pressure of 3.4 psi, Applied Normal to the Surface.

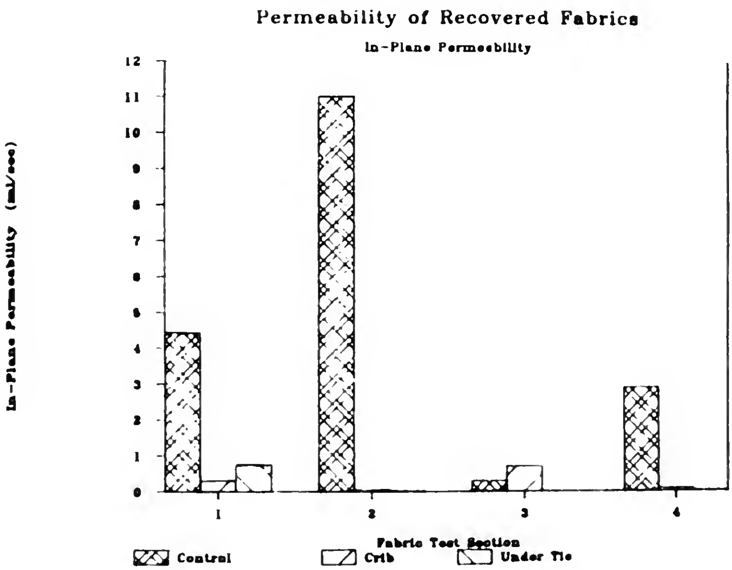

Figure 29. In-Plane Permeability of Geotextiles Recovered From the Field and Tested at a Pressure of 10 psi, Applied Normal to the Surface.

to system performance. The soil immediately adjacent to the fabric apparently has a tendency to increase in water content due to soil suction and local shearing by ballast particles [2]. Hoare has found that the water content of this thin clay soil layer may increase to the liquid limit and beyond. The fabric must remain sufficiently permeable to allow pore water, carrying the clay fines under pressure from transient loads, to escape into the fabric. In other words, the filtration properties of the geotextile should not be 100% efficient.

As evidence of this phenomenon, consider the fabric-related soil failure in Section 3. A derailment occurred that was directly related to the weak layer of clay particles that built up just under the clogged fabric. While it is not clear as to what extent the derailment was due to the differential rail settlement in Section 3, or the track sliding horizontally due to poor ballast-fabric soil frictional resistance, or both, the failure was clearly exacerbated due to an impermeable geotextile. Ballast sliding laterally on top of the fabric, due to a low coefficient of friction of the membrane-like fabric, also contributed to the track settlement, although to a lesser degree than than soil failure.

The grab strength test was used to determine the tensile resistance to tearing, when subjected to a slowly increasing load applied to either end of a standard sized strip. Fabric in a soiled and wet condition was tested in this manner; the results are shown in Figure 31 for samples recovered from under the tie and in the crib area. The fabric with the largest loss of strength, as compared to the control, was Fabric 1, which exhibited a 56% decrease. Fabric 2 had the least amount of strength loss, with only a 35% decrease.

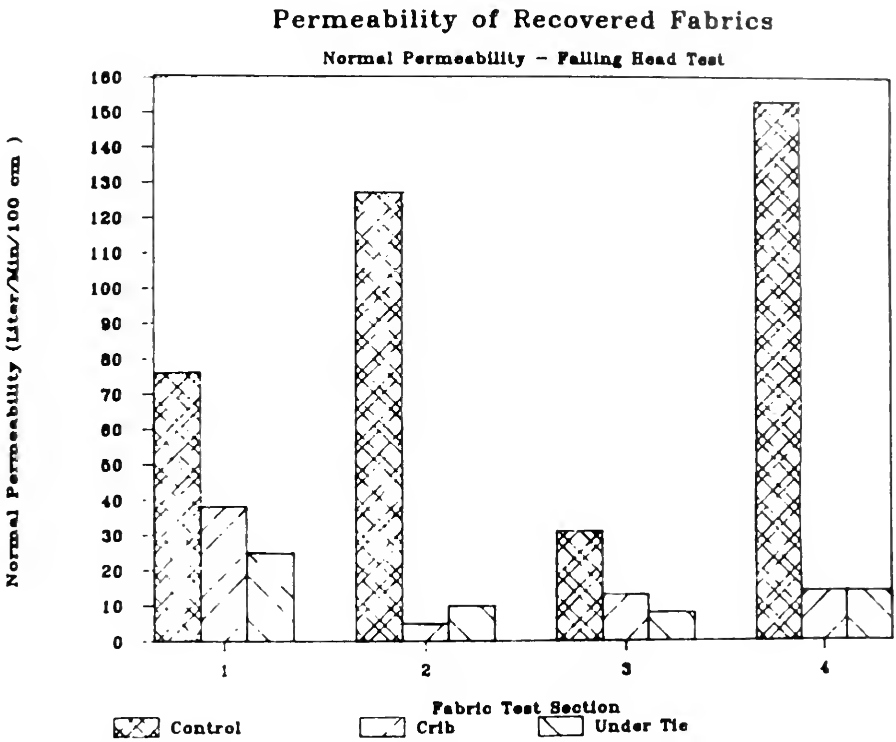

Figure 30. Normal Permeability of Geotextiles Recovered From the Field and Tested Under Falling-Head Conditions.

A visual inspection at the time of fabric sampling from the field revealed that Fabrics 3 and 4 had the most holes from tamper and traffic-induced ballast puncturing. Despite the relatively low amount of retained grab strength, Fabric 1 was observed in track to have the least number of puncture holes, although the surface of this fabric was somewhat more abraded than the other fabrics. Most of the holes were located in the area below the tie-rail intersection. The holes in the fabrics appeared to have been made by ballast puncturing rather than abrasion.

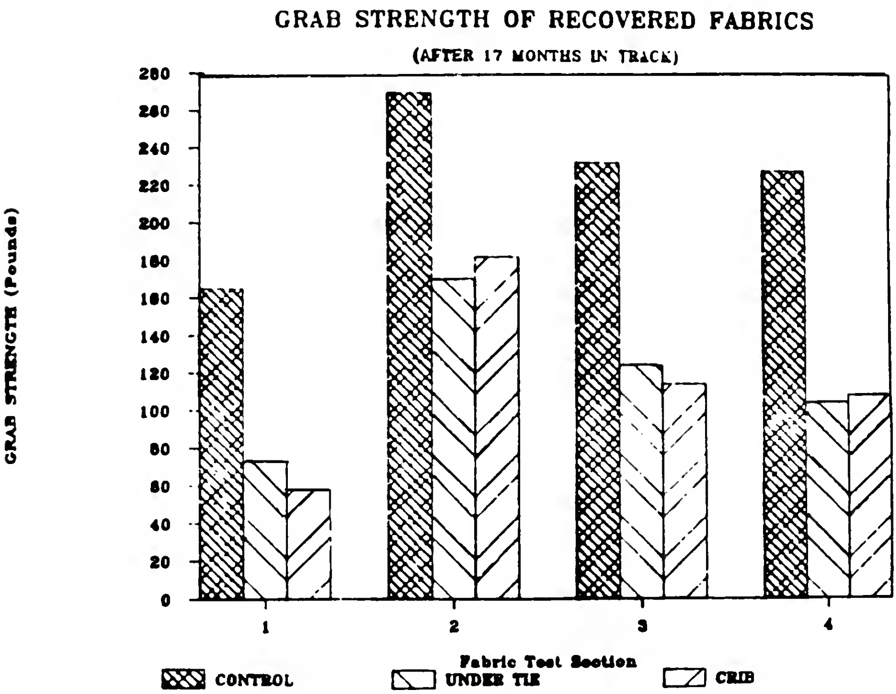

Figure 31. Grab Strength of Geotextiles Recovered From the Field and Tested Under Wet and Soiled Conditions.

7.0 ANALYSIS OF RESULTS

Any final analysis of the effect of geotextiles upon track behavior should compare how the track was postulated to be improved and determine to what extent, if any, the testing indicated such an improvement. Data gathered over the year and a half of testing will be analyzed in more detail in this section. The four postulated beneficial effects mentioned in Section 3.0 will now be reviewed, in light of what the various track measurements indicated.

7.1 Reinforcement

If track reinforcement was occurring, these effects would probably manifest themselves in a decreased amount of vertical deformation under load and decreased pressure transmitted to the subgrade. A review of the data from the subgrade pressure and extensometer transducers indicated that no such reinforcement effect was observed, when the instrument readings of Fabric Sections 1 through 4 were compared to those of the control (Section 5) and the cement-stabilized (Section 6) locations.

7.2 Subgrade Moisture Transport

Another anticipated benefit of geotextiles, that of moisture transport in the subgrade, could be assessed by the soil moisture measurements and the pore water pressure readings. Although the soil moisture measurements were not consistent among the different measurement methods, there was still enough evidence to conclude that there was no apparent subgrade moisture transport in the fabric sections, as compared to the control section. The maximum seasonal variation of subgrade moisture content in Section 5 was not significantly greater than that of the average of all of the fabric sections (see Figure 7).

The pore water pressure readings, although somewhat difficult to interpret, also did not support the moisture transport mechanism. The reduced pore pressures that one would expect to observe in the fabric sections, relative to the control section, if the fabrics did transport moisture, was not apparent.

7.3 Filtration/Separation

The real success of these geotextiles in separating the layers, and limiting any intermixing of the ballast and subgrade, could be seen by comparing the amount of fines above the fabric with the amount at the ballast/soil interface in the control section (Figure 25). The silty and clayey fines in the ballast of each fabric test section could be used to assess the filtration/separation functions of these geotextiles. There was a clear difference within the fabric sections with respect to the amount of subgrade fines contamination in the ballast. Of the fabric sections, Section 1 had the lowest amount of fines in the ballast, whereas Section 3 had the most.

As mentioned previously, filtration should not be 100% efficient. Passing some of the clayey fines that have access to the fabric should continue in order to prevent a buildup of these particles and a resulting weak soil layer.

7.4 Durability

The types of geotextiles in this test allow a comparison of needle-punched with thermal-bonded fabrics, and polyester with polypropylene fabrics. The type of thermal-bonded fabric used in Section 3 appears unsuitable for use in railroad track because of its low permeability and low ballast-fabric frictional resistance. The fabric with the polypropylene polymer (Fabric 1) seemed to perform the best with respect to resistance to both clogging and puncture damage. Although not mentioned before, Fabric 1 had the highest retained filament strength of all the fabrics recovered from the field. The percent of retained strength of filaments from the tops (sides that faced the ballast) of Fabrics 1 to 4 were, respectively, 90%, 57%, 34%, and 56%. There was, however, somewhat more abrasion on the surface of Fabric 1. Also, Fabric 1 had the greatest percentage loss in grab strength.

8.0 CONCLUSIONS

Geotextiles apparently provide varying degrees of filtration and separation to the track structure. These two functions could be enough to justify the inclusion of fabric in the track. If reinforcement and/or subgrade moisture transport also resulted, then this would be an added bonus. However, the data collected from this extensively instrumented test did not show any evidence of moisture transport or reinforcement attributable to the fabric.

The graphs of subgrade moisture from the soils, obtained by hand sampling for over one and one-half years, show seasonal changes in the soil in each section, but the observed moisture variations were virtually the same among the fabric sections and the control section. It is in the variation of subgrade moisture that one would expect to observe evidence of fabric-induced subgrade drainage.

Reinforcement due to fabric membrane support was also not indicated from either the earth pressure measurements or the soil extensometers.

Perhaps one of the most interesting findings was the geotextile-related track failure which resulted in a derailment in Section 3. The soil failure was in the form of a clay slurry which built up under a fabric with a very low initial permeability. Because the clay particles in the compacted clay loam were displaced upwards under the loading conditions, these fines accumulated at the fabric-soil interface. Furthermore, the local shearing of the soil just under the fabric probably caused a rise in the water content of the soil at this interface. The pore water carrying the clay fines could not escape through the fabric because of apparent fabric clogging. This clogging is thought to have been caused by the low permeability of the fabric. Low ballast-fabric frictional resistance may also have contributed to the excessive settlement in Section 3, because of insufficient lateral ballast restraint.

It appears that the installation of a geotextile that clogs can be more harmful than not installing one at all, as shown by the fact that Fabric Section 3 failed, while the control section was remarkably stable. Even though this particular type of thermal bonded fabric is no longer used in track, it does illustrate what could happen if a fabric became clogged. With the more permeable fabrics that railroads are using currently, clogging may not occur for many years. However, those fabric properties which resist clogging should be further investigated.

In summary, the Caldwell geotextile tests indicated that these fabrics did not play a direct structural role or modify the soil conditions in an active manner. The benefit of these materials appeared to be in their application as barriers to intermixing of the ballast and subgrade.

8.0 REFERENCES

1. Scott, J. F., "Granular Depth Requirement for Railroad Track," Presented at the Transportation Research Board Conference, Washington, D.C., January, 1985.

2. Hoare, D. J., "A Laboratory Study into Pumping Clay Through Geotextiles Under Dynamic Loading," Second International Conference on Geotextiles, Las Vegas, Nevada, 1982.

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