Transportation Test Center

FAST/HAL TIE AND FASTENER EXPERIMENTS

AAR REPORT NO. R-795
FRA/ORD-91/23

ASSOCIATION OF AMERICAN RAILROADS

U.S. Department of Transportation
Federal Railroad Administration

Facility for Accelerated Service Testing
Heavy Axle Load Program

FAST/HAL TIE AND FASTENER EXPERIMENTS

AAR REPORT NO. R-795
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by

Dave Read

Association of American Railroads
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13. Abstract

The objective of the Fast Accelerated Service Testing Heavy Axle Load Tie and Fastener Experiments was to quantify the performance of wood and concrete ties and associated fastening systems under the FAST Heavy Axle Load (HAL) train. The experiment was conducted on the 5- and 6-degree curves of the High Tonnage Loop (HTL), with total tonnage accumulation of 160 million gross tons (MGT).

There were no failures of any of the wood or concrete ties during the test period. Fastener stiffness measurements performed on wood ties indicated the cut spike system allowed at least twice the lateral rail head displacement of any elastic fastener at a L/V ratio of 0.5 (40,000 pounds vertical force and 20,000 pounds lateral force). The cut spikes also showed as much as five times the rate of lateral restraint degradation as the elastic fasteners over the 160 MGT period at the 0.5 L/V ratio. However, at L/V ratios of 0.25 or less, the lateral displacement allowed by the cut spikes were nearly identical to the elastic fasteners. Comparison of static rail rotation data taken during the 33-ton axle load phase of testing at FAST indicates 70-100 percent higher values are being recorded under the 39-ton axle load consist.

Flexural cracks were observed during the initial 90 MGT on 3 percent of the concrete ties in test. The cracks all occurred on the low rail side of the tie between the rail seat and the tie center and were caused by negative bending of the tie. Similar cracks were also observed on one of the concrete ties designed for tangent track. There were no new cracks noted after 90 MGT. None of the cracked ties were removed from track; some remained in service for 140 MGT after crack initiation. Similar cracking was not noted during the 33-ton axle load phase.

Measurable tie plate cutting was recorded only in the softwood ties in Section 25. The cutting occurred primarily on the field side of the high and low rail plates causing a decrease in the cant of the rails. Data from the 33-ton axle load phase of FAST indicated more vertical cutting of the plate, as opposed to the differential cutting seen during the HAL program. However, the amount of vertical cutting measured during both programs was very similar.

Dynamic strain data was collected on the tops of three consecutive Burlington Northern 100 concrete ties in Section 03 to quantify tensile strains produced by negative bending between the rail seats. The measurement was performed under a train of equal numbers of 33- and 39-ton axle load cars to determine the effect of increased axle load. The data indicated little difference in dynamic strain response due to axle loading, except at the tie centers where an approximate 13 percent increase was recorded for those strains above the 90th percentile of the distribution.

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EXECUTIVE SUMMARY

Measurements were taken to quantify the performance of wood and concrete ties and associated fastening systems under the Facility for Accelerated Service Testing (FAST) Heavy Axle Load train at the Transportation Test Center (TTC), Pueblo, Colorado. There were no significant failures of any test components during the 160 million gross tons (MGT) test period.

Data collected on wood ties indicated that the cut spike system allowed at least twice the lateral railhead displacement of any elastic fastener at a lateral force to vertical force (L/V) ratio of 0.5 (40,000 pounds vertical force and 20,000 pounds lateral force). However, at L/V ratios of 0.25 or less, the lateral displacement allowed by the cut spikes was nearly identical to the elastic fasteners. The cut spikes also showed a rate of lateral restraint degradation with tonnage which was five times higher than the rate measured with the elastic fasteners. The experiment was conducted in the 5-degree curve of Section 07 and the 6-degree curve of Section 25 at FAST. The measurements were performed using the TTC Rail Force Calibration Car (605 car), which applies static vertical and lateral forces to the rails. While under a constant vertical force of 40,000 pounds, lateral displacement of the railhead and base was measured at various lateral force levels.

Comparison of lateral rail base displacement (lateral translation of the rail) and rail rotation under static vertical and lateral forces with similar measurements taken during the 33-ton axle load phase of testing at FAST, indicated degradation rates of cut and elastic spike fasteners were 70-100 percent higher under the 39-ton axle loads after 160 MGT.

Dynamic strain data was collected on the tops of three consecutive BN 100 concrete ties in Section 03 to quantify tensile strains produced by negative bending between the rail seats. The measurement was performed under a train of equal numbers of 33- and 39-ton axle load cars to determine the effect of increased axle load. The data indicated little difference in dynamic strain response due to axle loading except at the tie centers where an approximate 13 percent increase was recorded for those strains above the 90th percentile of the distribution.

Flexural cracks were observed during the initial 90 MGT on 3 percent of the concrete ties in test in the 5-degree curve of Section 03. The cracks all occurred on the low rail side of the tie between the rail seat and the tie center and were caused by negative bending of the tie. Similar cracks were also observed on one of the concrete ties designed for tangent track. There were no new cracks noted after 90 MGT. None of the cracked ties were removed from track; some remained in service for 140 MGT after crack initiation. Similar cracking was not noted during the 33-ton axle load phase.

Measurable tie plate cutting was recorded only in the softwood ties in Section 25. The cutting occurred primarily on the field side of the high and low rail plates causing a decrease in the cant of the rails. Tie plate cutting data from the 33-ton axle load phase of FAST indicated more vertical cutting of the plate, as opposed to the differential cutting seen during the HAL program. However, the magnitude of vertical cutting measured during both programs was very similar and quite small.

Information concerning ties and rail fastening systems is necessary to determine the overall performance of the track structure under 39-ton axle loads. Accordingly, the objective of the FAST\HAL Tie and Fastener Experiment was to quantify the performance of wood and concrete ties and associated fastening systems under the FAST\HAL train. Total tonnage accumulation was 160 MGT. Test specimens included hardwood and softwood domestic ties, tropical hardwood ties (Azobe), as well as concrete ties from most of the primary revenue service users including the Burlington Northern Railroads, Canadian National Railways, AMTRAK, and Chessie Systems Railroads. Fastening systems included conventional cut spikes with rail anchors and elastic fasteners.

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INTRODUCTION

Performance testing of ties and fasteners has been a part of the Facility for Accelerated Service Testing Program since its inception in 1976. Between 1976 and 1987, during operation of the 33-ton axle load consist, a total of 12 different wood tie and fastener tests, three concrete tie and fastener tests, and a steel tie test were performed.[1] These tests involved a variety of timber tie types, including non-traditional types such as reconstituted and laminated ties, and many of the available concrete tie designs. Included with both timber and concrete ties were a wide variety of rail fastener systems.

The goal of the current FAST Heavy Axle Load (HAL) program is to determine the effects of operating 39-ton axle loads on performance of the basic track structure. To accomplish this goal, a set of experiments was designed and implemented to investigate the behavior of individual track components under HAL traffic. These experiments, including tests of wood and concrete ties and rail fastening systems, are for the most part, quite similar to the tests conducted during the 33-ton axle load phase. This similarity allows comparison of test results between the HAL program and previous tests to be made as a means of determining the impact of increased axle loading on component life and maintenance effort.

Tonnage was accumulated with a consist of 60-80 cars with vehicle weights of 315,000 pounds (39-ton axle load), and a few vehicles with weights of 263,000 pounds (33-ton axle load). The 39-ton axle load cars were either high side gondolas or covered hopper cars and were loaded with material to simulate normal revenue service lading. All cars were equipped with standard three-piece trucks and double roller type side bearings. The train operated at a nominal speed of 40 mph and in the counterclockwise direction 90 percent of the time (See Appendix A).

Former tie and fastener tests of most interest are the three wood tie and fastener tests conducted in Section 07 and the Phase IIb concrete tie test conducted in Section 03. These same locations are the primary test zones for the HAL wood and concrete tie and fastener tests. Unfortunately, the comparison has been hampered by lack of continuity in test components from one program to the next. This is especially true of wood tie fastening systems where many of the items tested in the late 70's and early 80's are no longer manufactured. However, because the principal wood tie fastener in revenue service remains the cut spike, performance comparisons can be made of this system.

This report is divided into two parts: Part I is the Wood Tie and Fastener Test and Part II the Concrete Tie Test.

PART I - WOOD TIE AND FASTENER EXPERIMENT

1.0 INTRODUCTION AND OBJECTIVE

The timber crosstie equipped with canted tie plates, cut spike rail fasteners, and rail anchors has been, and continues to be, the predominant type of railway track construction in North America. Despite the general use of cut spikes as rail fasteners, their tendency to loosen over time, allowing gage spreading and rail roll-over under vehicle curving forces, has long been realized as a limitation of the cut spike system by track engineers.[2] As a means of increasing lateral rail stiffness, the use of elastic or direct fixation type rail fasteners on wood ties has steadily increased in response to higher vehicle weights and applied lateral forces. The objective of the Wood Tie and Fastener Experiment is to determine what effect increasing the nominal freight car axle load from 33 tons to 39 tons has on the performance of various types of wood ties and rail fastening systems. Performance determination is based on specific measurements, including:

1. Fastener performance as determined by:
   - measurements of lateral railhead and base displacements under static and dynamic loading.
   - numbers of fastener failures and maintenance demand.
2. Tie plate cutting rates for different wood species.
3. Deterioration of the as-built track geometry.
4. Visual inspection of ties for splits and checks.

2.0 DESCRIPTION OF TEST ZONES AND TEST COMPONENTS

At the beginning of the HAL program, test zones were established in the 5-degree curve of Section 07 and the 6-degree curve of Section 25. The zones were divided into subsections of 100 ties, each having a different rail fastening system or tie size. One subsection in Section 25 contained 6"x8"x8'6" ties while all other subsections had 7"x9"x8'6" ties. All but one subsection was made up of 80 hardwood (mixed hardwood) and 20 softwood (fir) ties. All ties were new when installed and were spaced at 19.5-inch centers.

At 15 MGT into the program, 100 Azobe (tropical hardwood) ties were installed in the 5-degree curve of Section 31 on 19.5-inch centers. Half of the ties were equipped with American Railway Engineering Association (AREA) 14-inch tie plates with four cut spikes per tie plate, and the other half were equipped with AREA tie plates with Hoesch double elastic spikes. At 100 MGT, 80 additional Azobe ties were installed in Section 31 on 24-inch centers. Half of these ties were equipped with the Hoesch double elastic spikes, and the other half were equipped with Pandrol plates, E clips, and 15/16-inch-diameter by 6-inch-long coach screws. It should be noted that the Azobe test zone is alongside the HTL Bypass Track. Also included in the HTL, but not specifically part of this test, were cross grain laminated fir ties that were installed in 1978 and had accumulated about 750 MGT of 33-ton axle load traffic.[1] A description of the various subsections is included in Table 1, and the layout of the wood tie test zones and pictures of the fastening systems are shown in Figures 1 through 7.

Table 1. Description of Wood Tie and Fastener Test Components

TIE TYPE	FASTENING SYSTEM	TIE SIZE	TIE SPACING	HAL TONNAGE (MGT)
SECTION 07				
Domestic hard/softwood	AREA 14"x7.75" tie plate w/4 cut spikes per plate every 2nd tie anchored	7"x9"x8'6"	19.5"	160
Domestic hard/softwood	AREA 14"x7.75" tie plate w/Koppers elastic fastener	7"x9"x8'6"	19.5"	160
Domestic hard/softwood	Pandrol tie plate w/Pandrol E clip 4 lock spikes per plate	7"x9"x8'6"	19.5"	160
Domestic hard/softwood	AREA 14"x7.75" tie plate w/American Track Systems double elastic spikes	7"x9"x8'6"	19.5"	160
Domestic hardwood	AREA 14"x7.75" tie plate w/McKay elastic fastener	7"x9"x8'6"	19.5"	158
SECTION 25				
Domestic hard/softwood	AREA 14"x7.75" tie plate w/4 cut spikes per plate every 2nd tie anchored	6"x8"x8'6"	19.5"	160
Domestic hard/softwood	AREA 14"x7.75" tie plate w/5 cut spikes per plate every 2nd tie anchored	7"x9"x8'6"	19.5"	160
Domestic hard/softwood	AREA 14"x7.75" tie plate w/4 cut spikes per plate every 2nd tie anchored	7"x9"x8'6"	19.5"	160

Table 1. Description of Wood Tie and Fastener Test Components -- (Continued)

TIE TYPE	FASTENING SYSTEM	TIE SIZE	TIE SPACING	HAL TONNAGE (MGT)
SECTION 31				
Azobe	AREA 14"x7.75" tie plate w/4 cut spikes per plate every 2nd tie anchored	7"x9"x8'6"	19.5"	92*
Azobe	AREA 14"x7.75" tie plate w/Hoesch double elastic spikes	7"x9"x8'6"	19.5"	92*
Azobe	AREA 14"x7.75" tie plate w/Hoesch double elastic spikes	7"x9"x8'6"	24"	7**
Azobe	Pandrol plates w/E clips 4 each 15/16" x 6" coach screws	7"x9"x8'6"	24"	7**

* Ties installed at 15 MGT - lower tonnage due to Bypass Track operation.
** Ties installed at 100 MGT - lower tonnage due to Bypass Track operation.

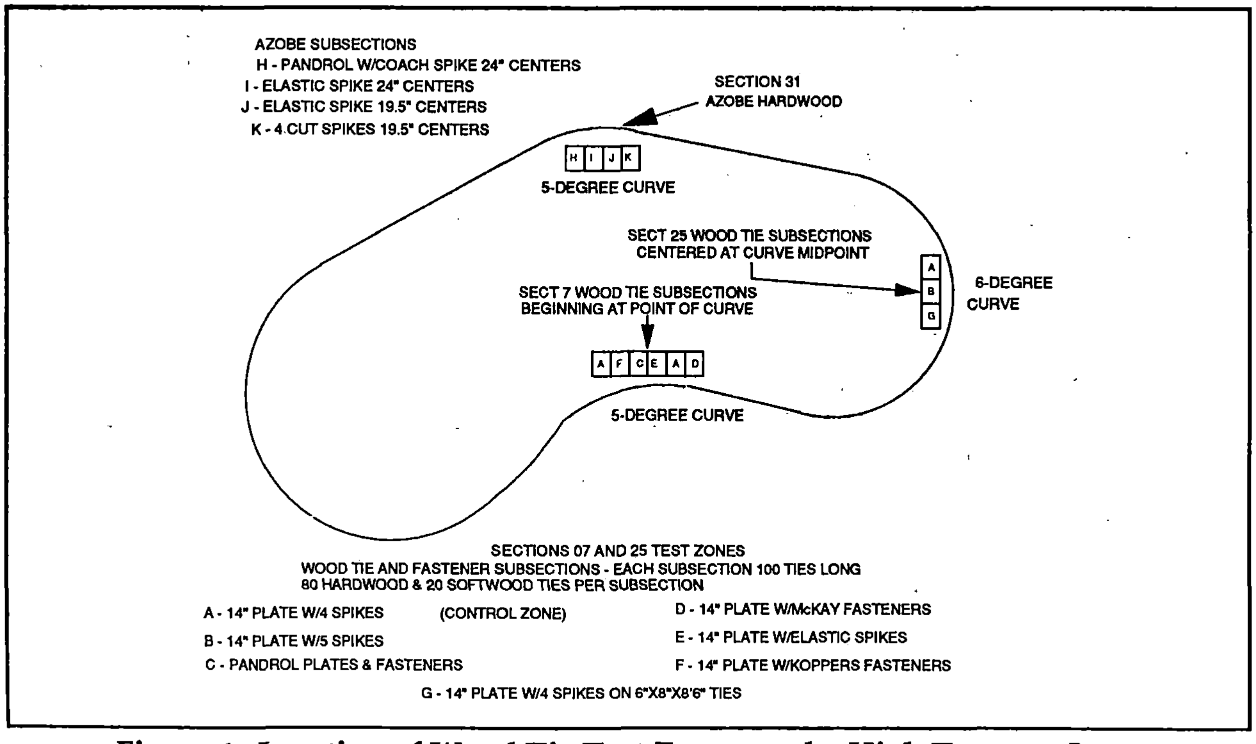

Figure 1. Location of Wood Tie Test Zones on the High Tonnage Loop and Configuration of the Subsections

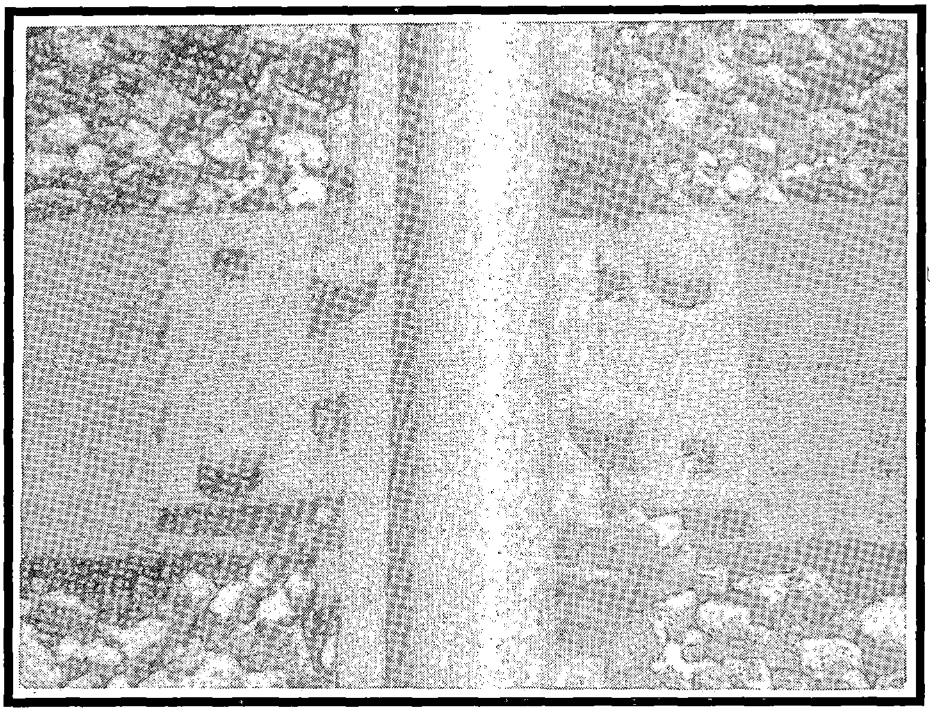

Figure 2. Subsection A -- 14" AREA Tie Plate with Four Cut Spikes

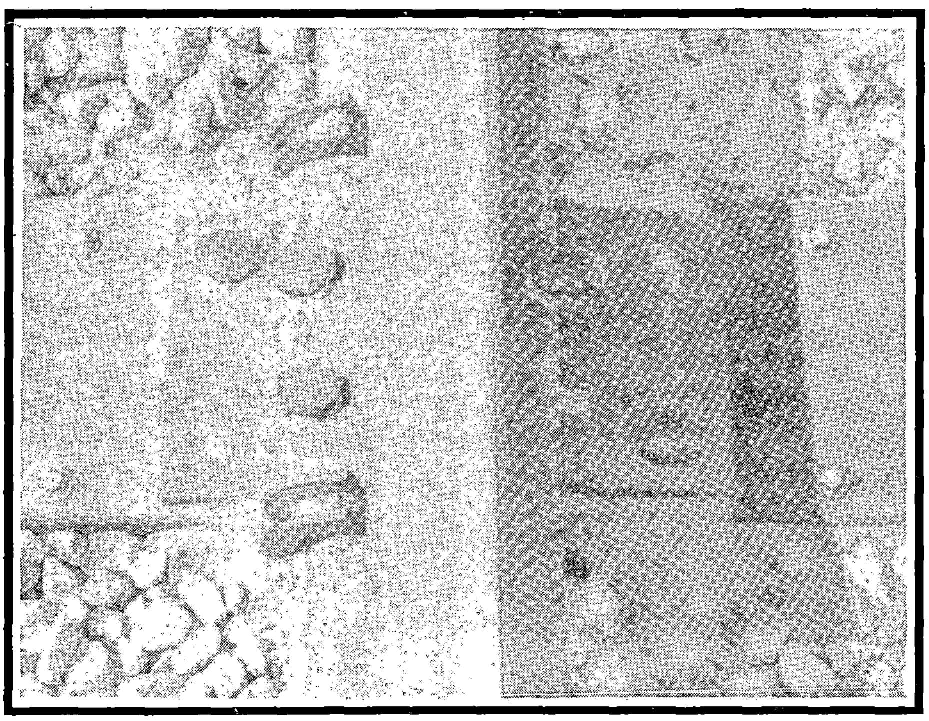

Figure 3. Subsection B -- 14" AREA Tie Plate with Five Cut Spikes

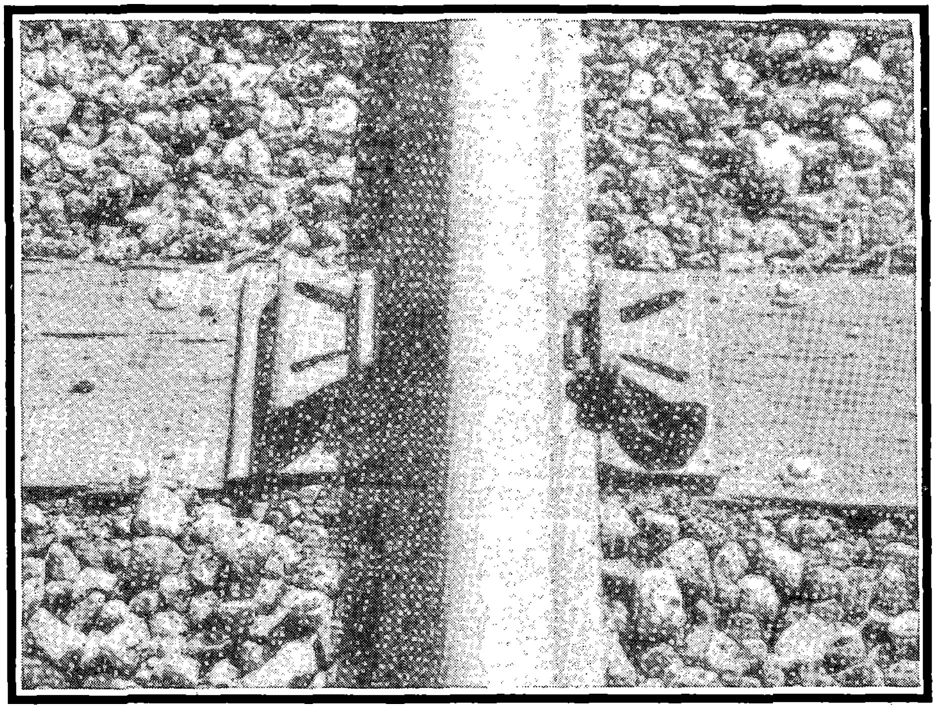

Figure 4. Subsection C -- 14" AREA Tie Plate with Koppers Fastener

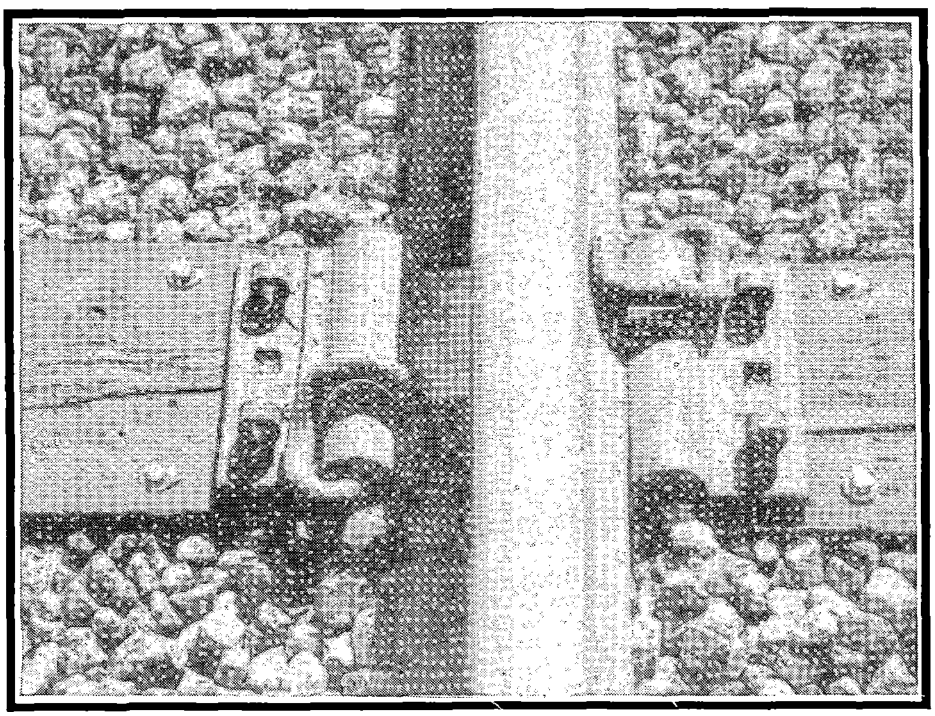

Figure 5. Subsection D -- 15.75" Pandrol Tie Plate with Pandrol E Clip

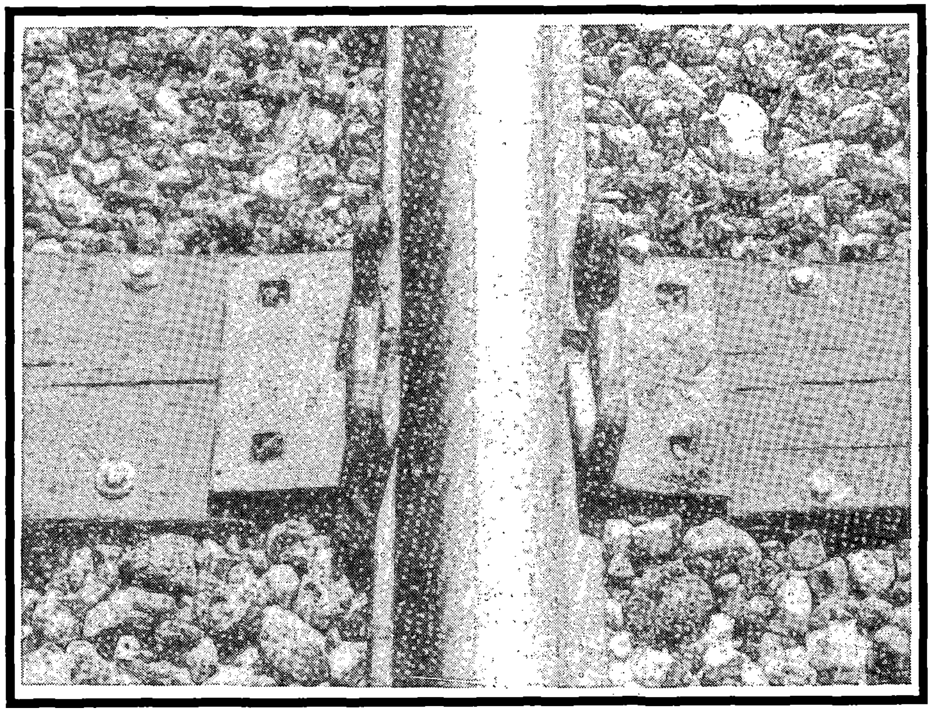

Figure 6. Subsection E -- 14" AREA Tie Plate with Double Elastic Spikes

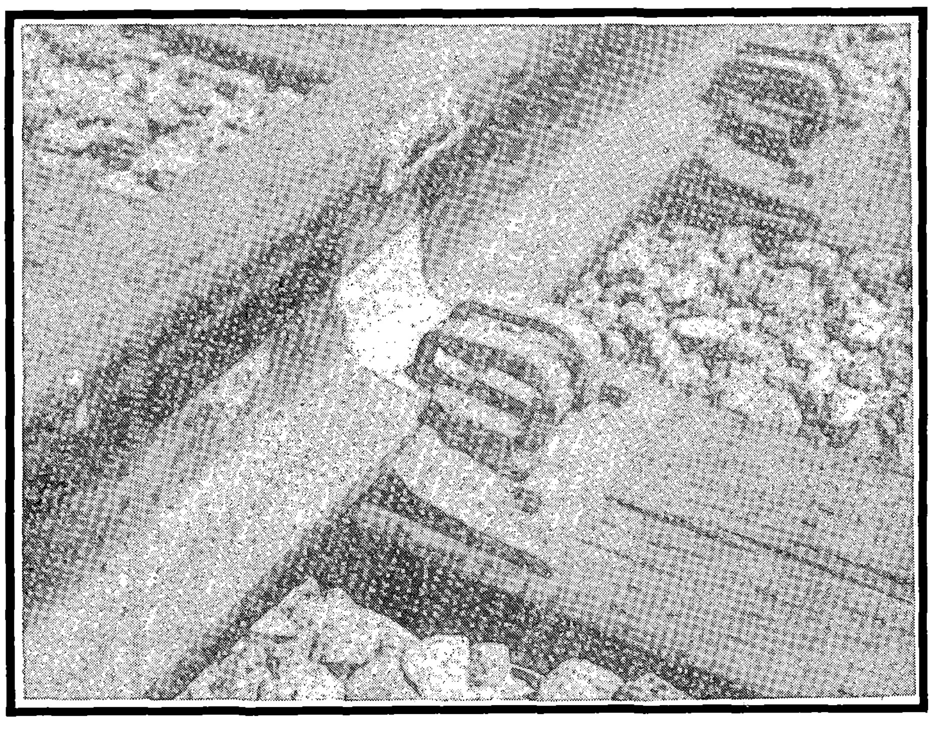

Figure 7. Subsection F -- 14" AREA Tie Plate with McKay Fastener

All test zones had either 132-, 133- or 136-pound continuous welded rail. Ballast in Section 07 was a slag material, and granite ballast was used in Sections 25 and 31. The ballast section was similar in all three zones with 12 inches to 15 inches beneath the ties, 12-inch to 15-inch shoulders and 1.5:1 slopes. The 5-degree curves had 4 inches of superelevation and the 6-degree curve had 5 inches.

All ties were installed using the same basic procedure. About 6 inches of ballast was removed beneath the ties using a Canron Track-Gopher; the existing ties were removed, and the pre-plated test ties were installed under existing rail. Track was re-ballasted and brought to final profile and alignment.

3.0 WHEEL/RAIL FORCES

The wheel/rail forces in the test zones were measured with instrumented rails (wayside) and instrumented wheel sets (vehicle borne). The distribution of peak vertical and peak lead-axle lateral rail forces, produced by each wheel in the consist (locomotive wheel forces have been deleted) at a single wayside location near the Section 07 curve mid-point, is shown in Figures 8 and 9, respectively. The data in both distributions was collected at 80 MGT with the HAL train operating at 40 mph in a counterclockwise direction and is the sum of 33 consecutive train passes.

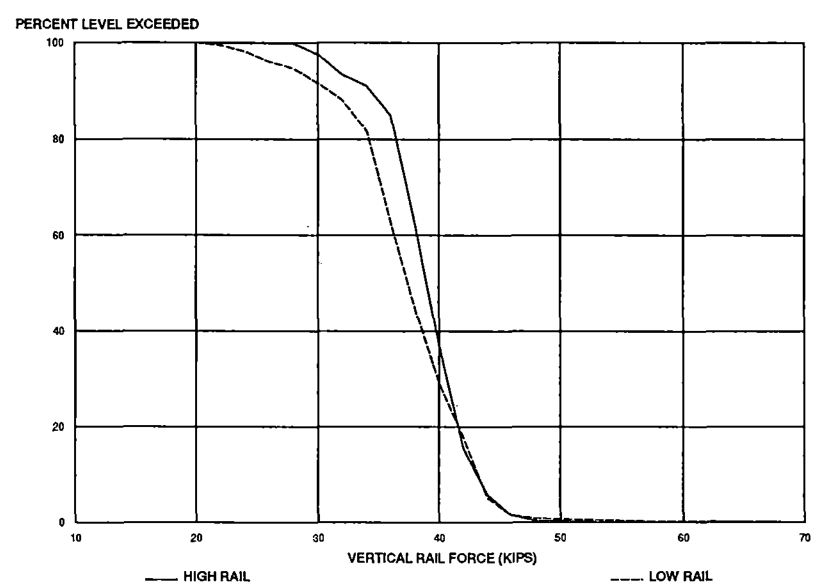

Figure 8. Distribution of Wayside Vertical Rail Forces Measured at the Mid-Point of Section 07

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March 11, 1992

OAVP/RAA/91-186

VTS Executive Committee

Gentlemen:

Enclosed is a copy of AAR Report R-795 entitled "FAST Heavy Axle Load Tie and Fastener Experiment," by Dave Read.

This report presents the results of field tests conducted at the Facility for Accelerated Service Testing concerning the performance of timber and concrete cross ties and rail/tie fastening systems under 39-ton axle loads. Where possible, results from the heavy axle load tests were compared to data generated under the 33-ton axle load train at FAST.

This report is based on an accumulated tonnage of 160 MGT of heavy axle load traffic. The experiment continues under the HAL extension program.

Sincerely,

Roy A. Allen
Assistant Vice President

cc: G. H. Way
S. B. Harvey
Research Committee
FAST Steering Committee
Engineering Division General Committee

ASSOCIATION OF AMERICAN RAILROADS | RESEARCH AND TEST DEPARTMENT | REPORT BRIEF

FAST/HAL TIE AND FASTENER EXPERIMENTS

R-795

December 1991

Measurements were taken to quantify the performance of wood and concrete ties and associated fastening systems under the Facility for Accelerated Service Testing (FAST) Heavy Axle Load (HAL) train at the Transportation Test Center, Pueblo, Colorado. There were no significant failures of any test components during the 160 million gross tons (MGT) test period.

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Copies of the AAR Report: "FAST/HAL Tie and Fastener Experiments," are available from the Document Distribution Center, Chicago Technical Center, 3140 South Federal Street, Chicago, Illinois 60616. The AAR report number is R-795; the price is $10.00 for member railroads and $100.00 for nonmembers. Illinois residents please add 8% sales tax. The cost includes surface mail postage if mailed within North America. There will be a surcharge for any overseas mail. Checks should be made payable to the Association of American Railroads. This report was issued in December, 1991. A report list is available upon request.

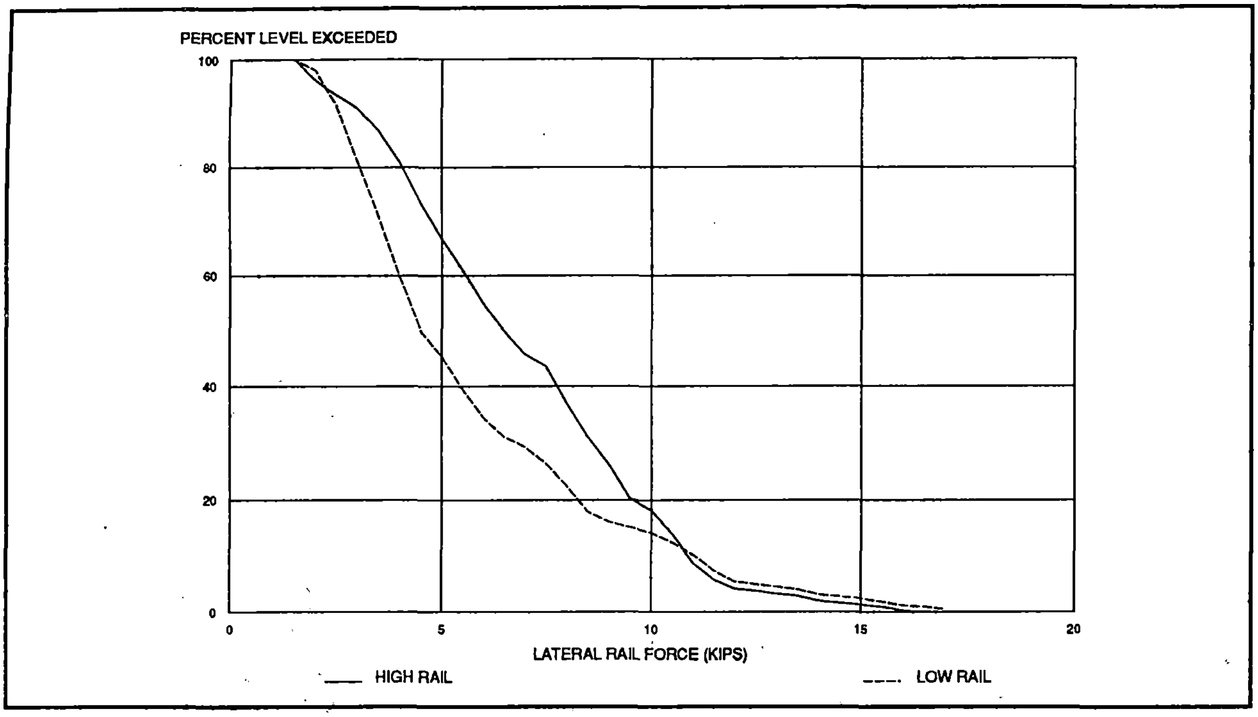

Figure 9. Distribution of Wayside Lead-Axle Lateral Rail Forces Measured at the Mid-Point of Section 07

Time history plots of continuous lead-axle vertical and lateral wheel force data, recorded with an instrumented wheel set at 100 MGT in Section 07, are shown in Figures 10-13. Wheel force data was collected with the instrumented wheel set installed in the leading truck of a fully loaded HAL car traveling 40 mph. The plots show the cyclic nature of dynamic force input into the track structure and give an indication of the forces present in each Section 07 tie/fastener subsection.

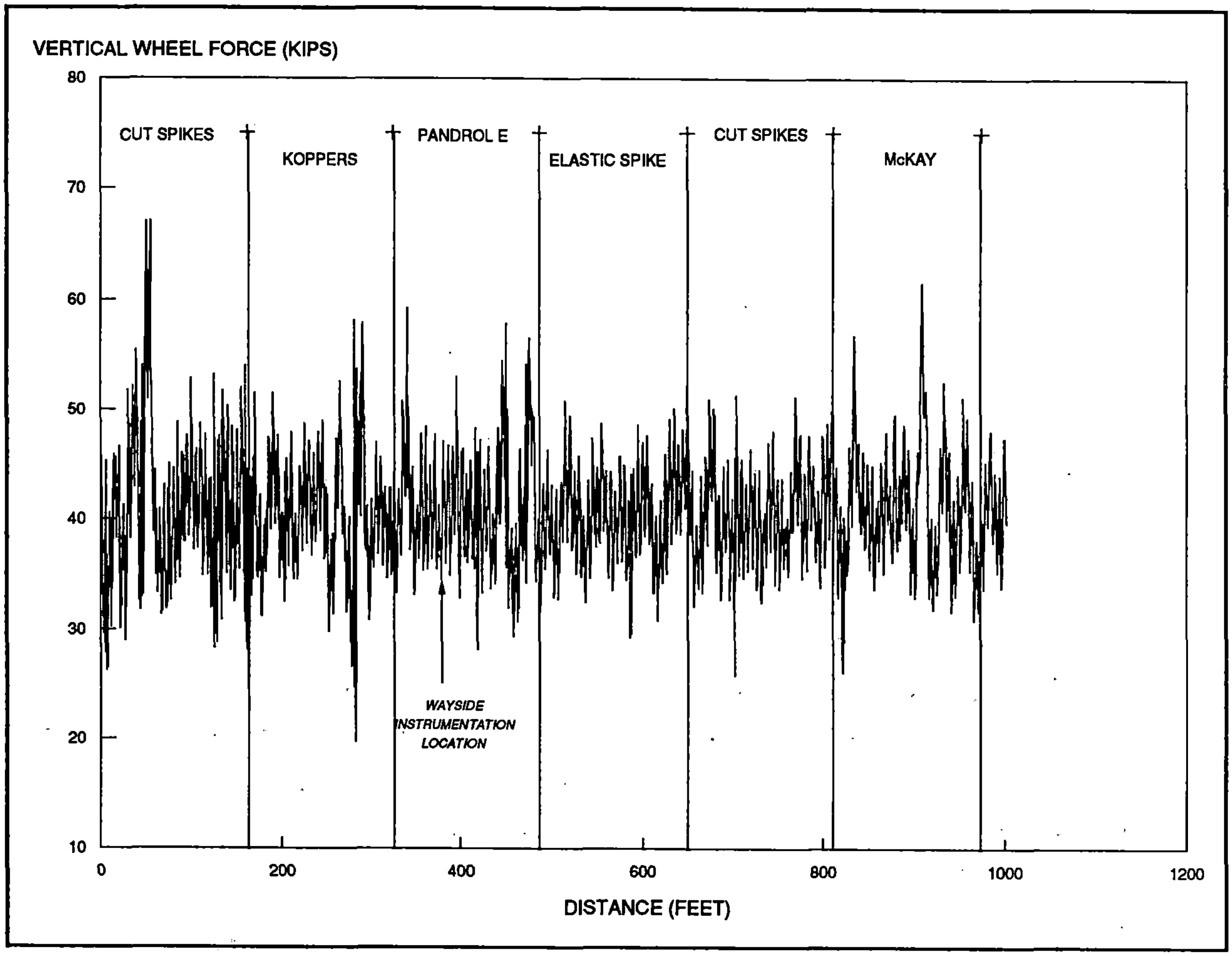

Figure 10. High Rail Lead-Axle Vertical Wheel Force Data Recorded in the Section 07 Wood Tie Zone

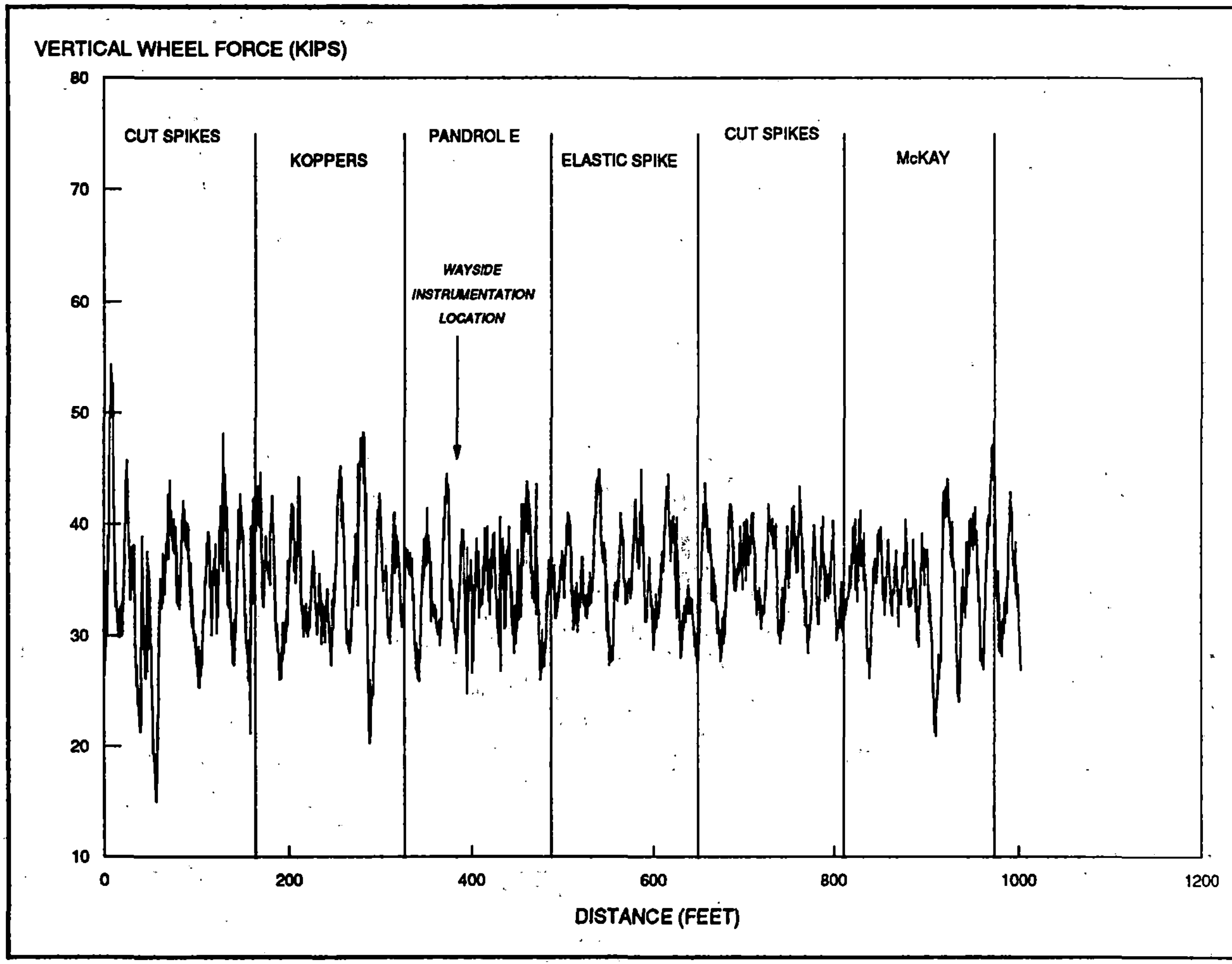

Figure 11. Low Rail Lead-Axle Vertical Wheel Force Data Recorded in the Section 07 Wood Tie Zone

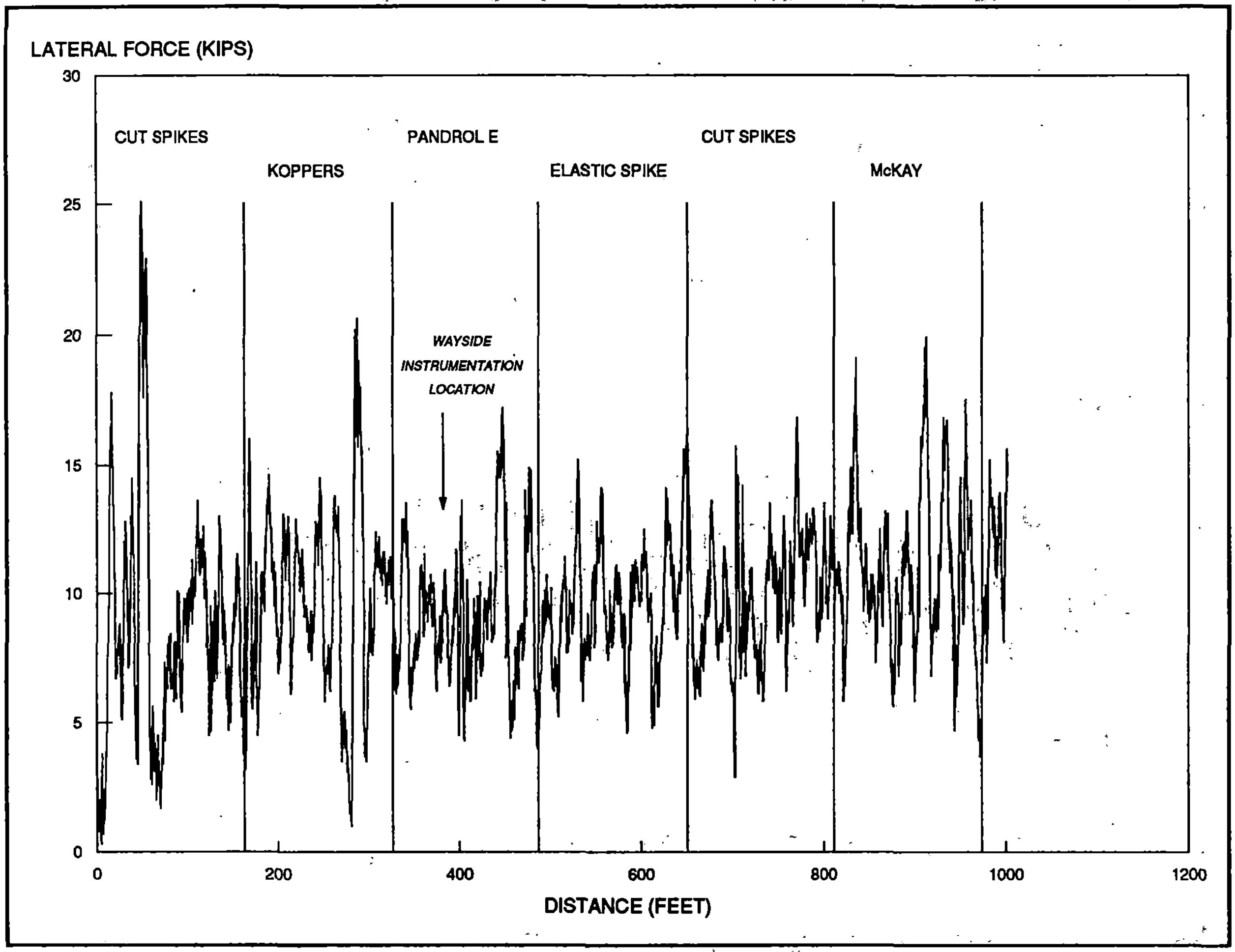

Figure 12. High Rail Lead-Axle Lateral Wheel Force Data Recorded in the Section 07 Wood Tie Zone

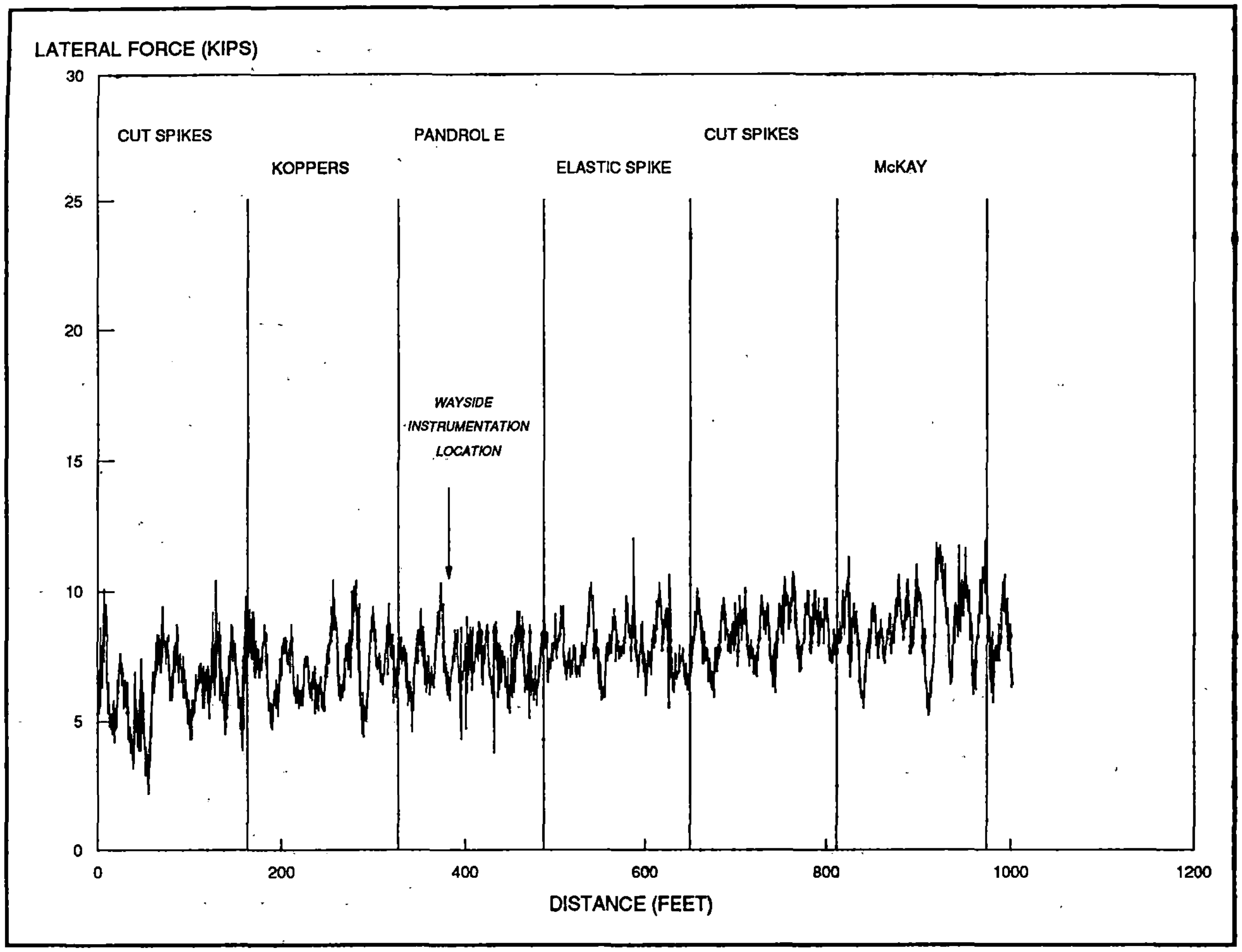

Figure 13. Low Rail Lead-Axle Lateral Wheel Force Data Recorded in the Section 07 Wood Tie Zone

Dynamic wheel forces were also measured in the Section 25 and 31 test zones at 100 MGT and are summarized in Table 2. In each table, the average and maximum lead-axle vertical and lateral wheel forces, and lead-axle L/V ratios are tabulated. The subsections where maximum values were recorded are also indicated in the tables.

Table 2. Wood Tie Test Zone Average and Maximum Lead-Axle Wheel Force Values

FORCE VALUE (KIPS)	LOW RAIL	HIGH RAIL
Section 07		
Vertical Average	34	40
Vertical Maximum	54 Cut Spike Subsection	67 Cut Spike Subsection
Lateral Average	7.6	9.7
Lateral Maximum	12.0 Elastic Spike Subsection	25.1 Cut Spike Subsection
L/V Average	0.22	0.24
L/V Maximum	0.52 McKay Subsection	0.60 Koppers Subsection
Section 25		
Vertical Average	34	44
Vertical Maximum	45 All Subsections	56 6"x8" Subsection
Lateral Average	15.3	17.5
Lateral Maximum	19.7 4 Cut Spike Subsection	26.0 5 Cut Spike Subsection
L/V Average	0.44	0.38
L/V Maximum	0.55 4 Cut Spike Subsection	0.52 4 Cut Spike Subsection
Force Value (kips)	Low Rail	High Rail
Section 31 Azobe Tie Zone		
Vertical Average	31	45
Vertical Maximum	49 Elastic Spike 19.5" Subsection	59 Cut Spike Subsection
Lateral Average	9.6	11.5
Lateral Maximum	16.2 Elastic Spike 24" Subsection	21.2 Elastic Spike 24" Subsection
L/V Average	0.29	0.26
L/V Maximum	0.40 Elastic Spike 24" Subsection	0.39 Elastic Spike 24" Subsection

4.0 FASTENER PERFORMANCE

4.1 STATIC FORCE/DISPLACEMENT DATA

One method of quantifying fastener performance is to apply known vertical and lateral forces to the rail and measure the lateral rail displacement relative to the tie. Force and displacement measurements were taken using the TTC Rail Force Calibration Car (605 car) as a stationary force application device. The 605 car is equipped with hydraulic cylinders and load cells capable of producing and measuring vertical forces of 50,000 pounds on both rails and lateral gage-spreading forces of 25,000 pounds (Figure 14).

The static force/displacement measurement is performed by first applying a 40,000 pound vertical force to both rails to approximate the static wheel load. A gage-spreading lateral force is then applied in 5,000 pound increments to a maximum of 20,000 pounds. Lateral rail displacement is measured at the head and base of both rails at each lateral force step.

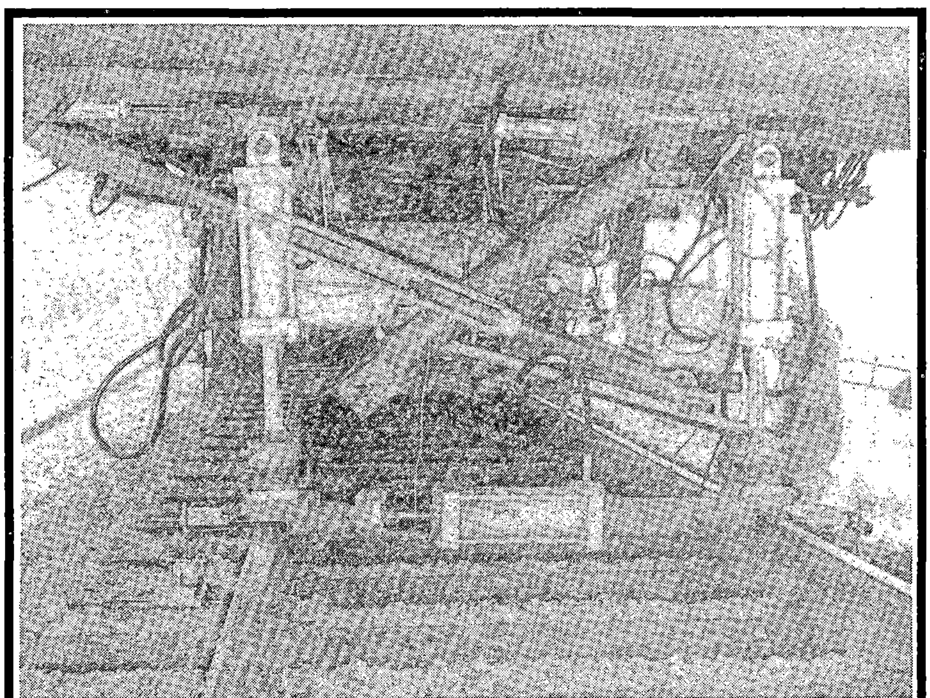

Figure 14. Vertical/Lateral Actuators and Load Cells of the 605 Car

A bar chart showing the average lateral railhead displacement of each fastener type in Section 07 is shown in Figure 15. Data shown in the figure is the average of 10 measurements, 5 low rail and 5 high rail, per measurement cycle with the same ties being measured at each measurement cycle. Average displacements in the graph were recorded at an applied static vertical force of 40,000 pounds and lateral force of 20,000 pound lateral (0.5 L/V ratio). The zero MGT displacement for the McKay fastener is missing because the fastener was installed at 2.5 MGT, and the measurement was not taken.

In Figure 16, the increase, after 160 MGT, in the average lateral railhead displacement from that measured at zero MGT is plotted for cut spike, Pandrol and double elastic fasteners in Section 07. Again, the displacement values were measured at static rail forces of 40,000 pounds vertical and 20,000 lateral.

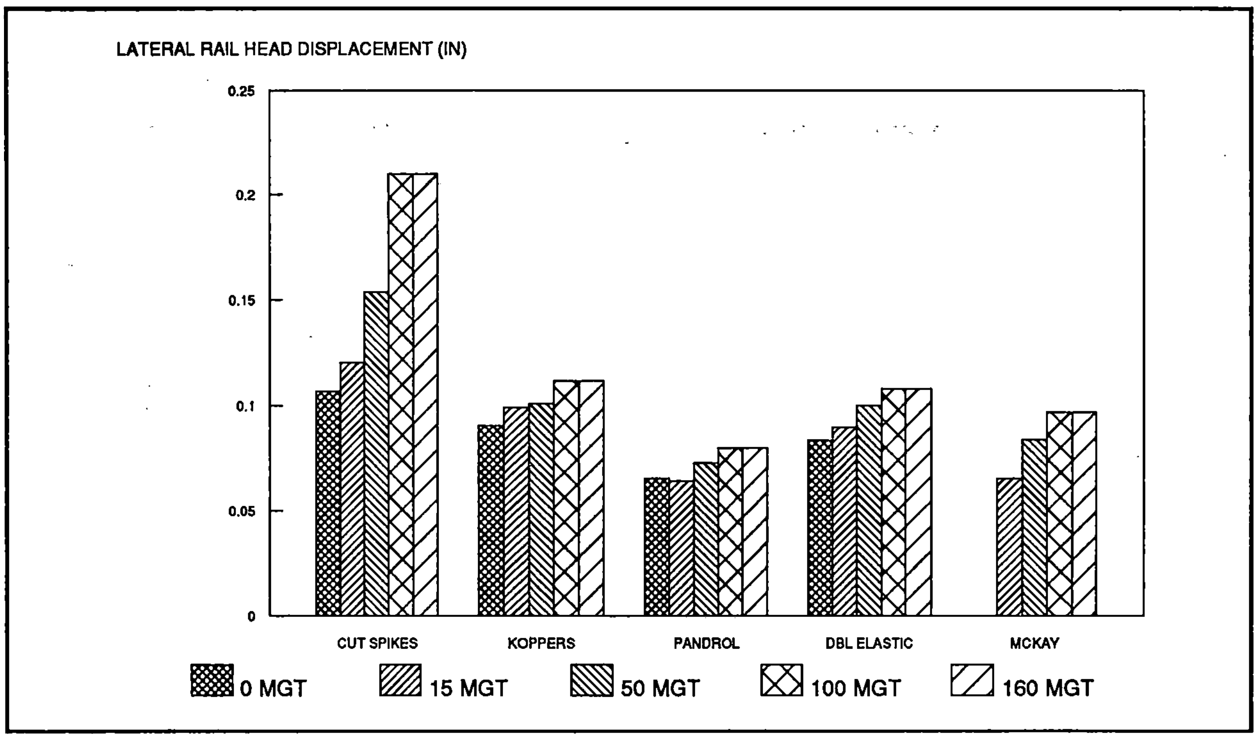

Figure 15. Average Lateral Railhead Displacement Allowed by Fastener Types in Section 07

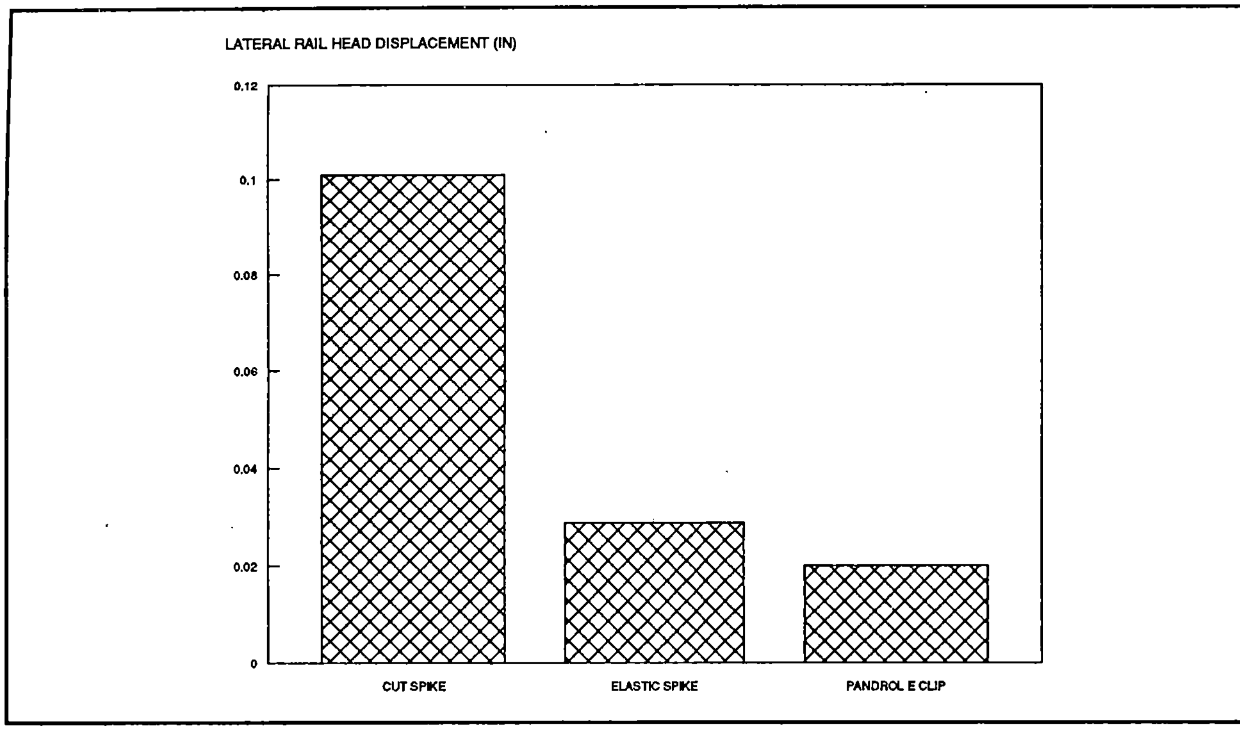

Figure 16. Increase in Lateral Railhead Displacement After 160 MGT for Cut Spike, Pandrol, and Double Elastic Spike Fasteners in Section 07

It is obvious from Figures 15 and 16 that lateral rail restraint provided by the cut spike system is considerably less than the restraint provided by the elastic fasteners at an applied vertical and lateral force which is equivalent to a L/V ratio of 0.5. However, if the entire force/displacement curve is plotted for each fastener type, as in Figure 17, where a vertical force of 40,000 pounds is constant and the lateral force is increasing, there appears to be little difference in lateral restraint provided by various systems at L/V ratios of 0.25 or less. In Figure 17, the average displacement of each fastener type in Section 07 as well as the five cut spike and smaller tie dimension subsections of Section 25, is plotted for each 5,000 pound increment of lateral force. Data in Figure 17 was recorded at 160 MGT.

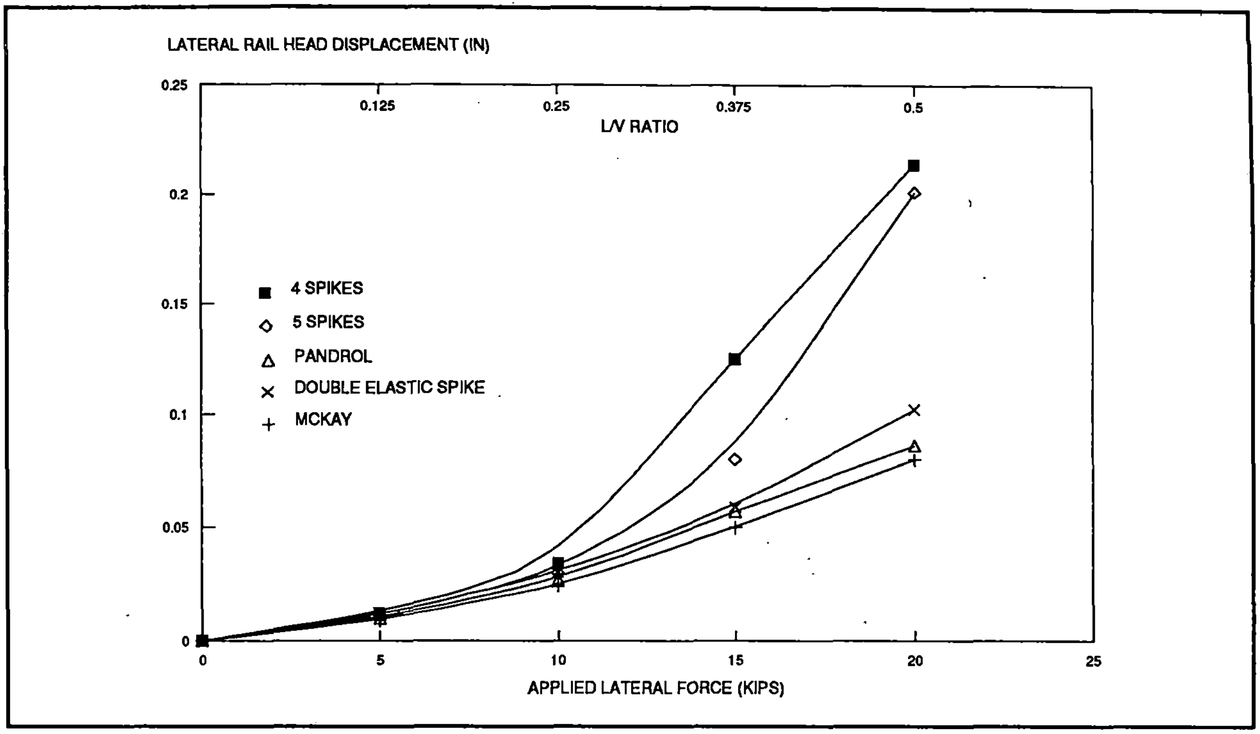

Figure 17. Lateral Rail Force and Displacement Curves for Section 07 Fastener Types at 160 MGT

Unfortunately, due to differences in the rail fasteners under test, comparison of fastener performance between the 33- and 39-ton axle load programs is limited to the cut spike and double elastic spike subsections in Section 07. In Figures 18-21, plots comparing rail base displacement and rail rotation recorded during the 33- and 39-ton axle load programs give an indication of cut and elastic spike performance differences due to increased axle loads. Thirty three-ton axle load displacement values were recorded at a static lateral force of 15,000 pounds and a vertical force of 33,000 pounds (L/V ratio of 0.45). The 39-ton axle load data was recorded with 40,000 pounds of vertical force; therefore, displacements at 0.45 L/V ratios were not measured. Thus, in Figures 18-21, two curves for the 39-ton axle load data are shown; data taken at a lateral force of 15,000 pounds (L/V ratio of 0.375) and a lateral force of 20,000 pounds (L/V ratio of 0.50).

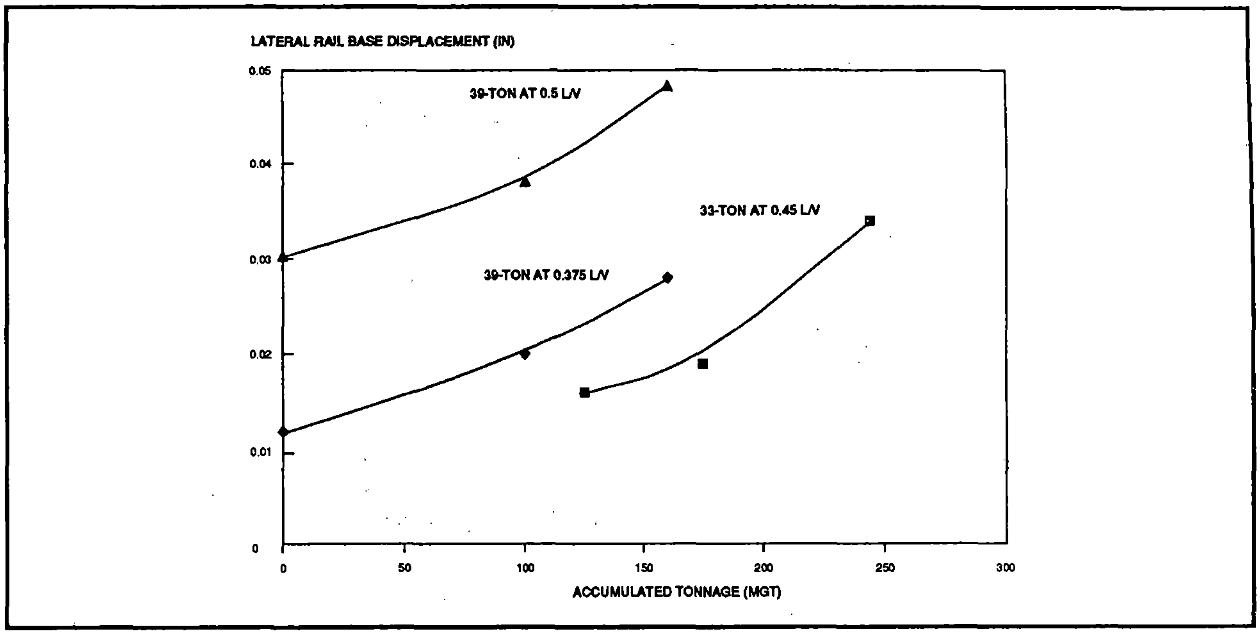

Figure 18. Comparison of Cut Spike Rail Base Displacement Data Recorded During 33-Ton and 39-Ton Axle Load Programs

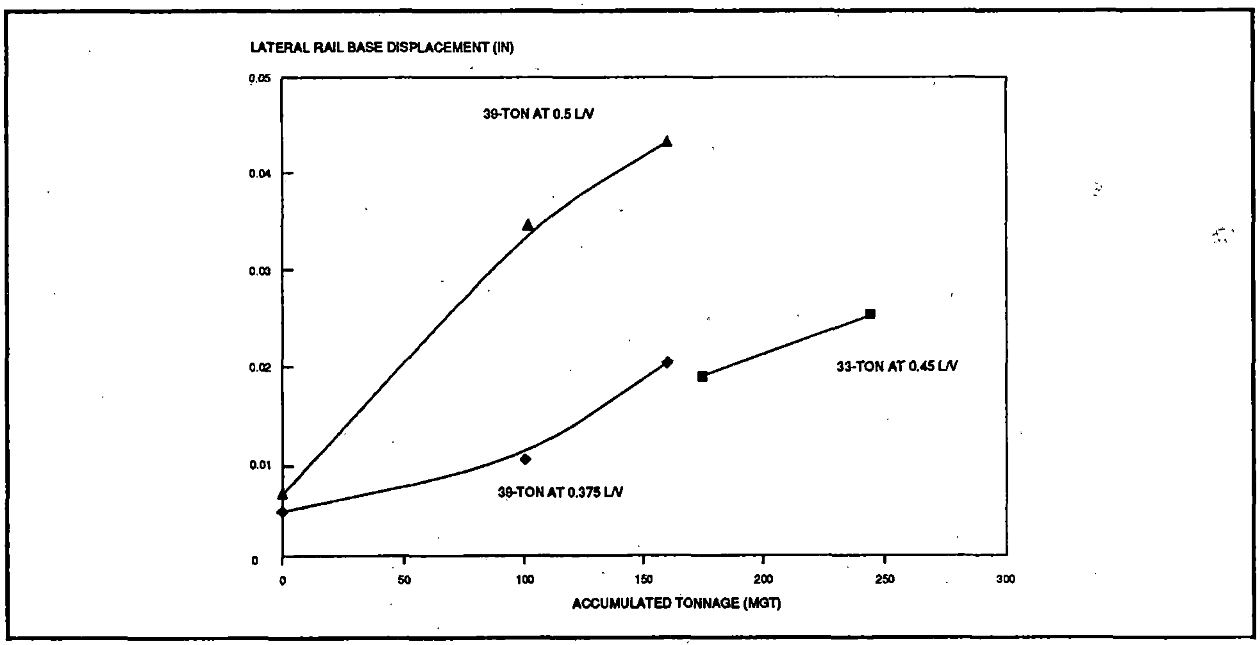

Figure 19. Comparison of Double Elastic Spike Rail Base Displacement Data Recorded During 33- and 39-Ton Axle Load Programs

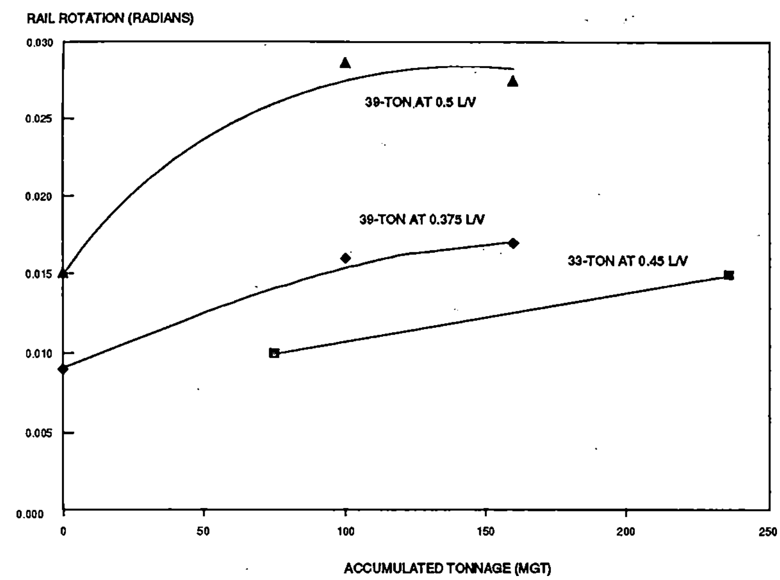

Figure 20. Comparison of Cut Spike Rail Rotation Data Recorded During 33- and 39-Ton Axle Load Programs

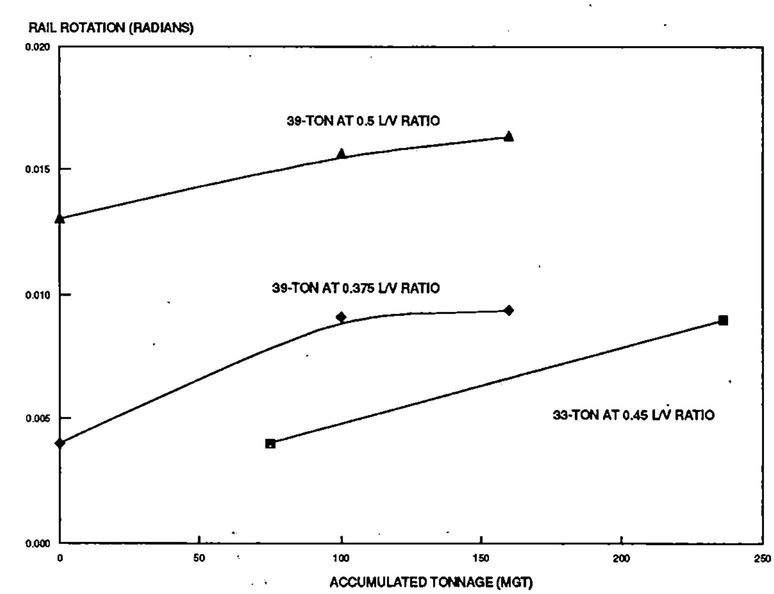

Figure 21. Comparison of Double Elastic Spike Rail Rotation Data Recorded During 33- and 39-Ton Axle Load Programs

The data in Figures 18-21 suggests that rail fastened with cut or elastic spikes on softwood ties may reach gage spreading limits sooner under 39-ton axle loads than under 33-ton axle load traffic. However, reliable estimation of lateral rail restraint degradation cannot be established after only 160 MGT of traffic.

Another important aspect of fastener performance under HAL conditions is the behavior of the systems on hardwood and softwood ties. In Figure 22, the average lateral railhead displacement of the four cut spike, five cut spike, elastic spike, and Pandrol systems on hardwood and softwood ties in Section 07 is compared at 160 MGT. In Figure 23, the lateral railhead displacement increase over zero MGT values, is compared for hardwood and softwood ties after 160 MGT. Fastener performance on the Azobe ties is shown in Figure 24 where the average lateral railhead displacements measured on the Azobe ties at 92 MGT is compared with the average displacements measured on the domestic hardwood and softwood ties with similar fastening systems at 100 MGT. In Figures 22-24, the displacement values were recorded at a static vertical force of 40,000 pounds and lateral force of 20,000 pounds.

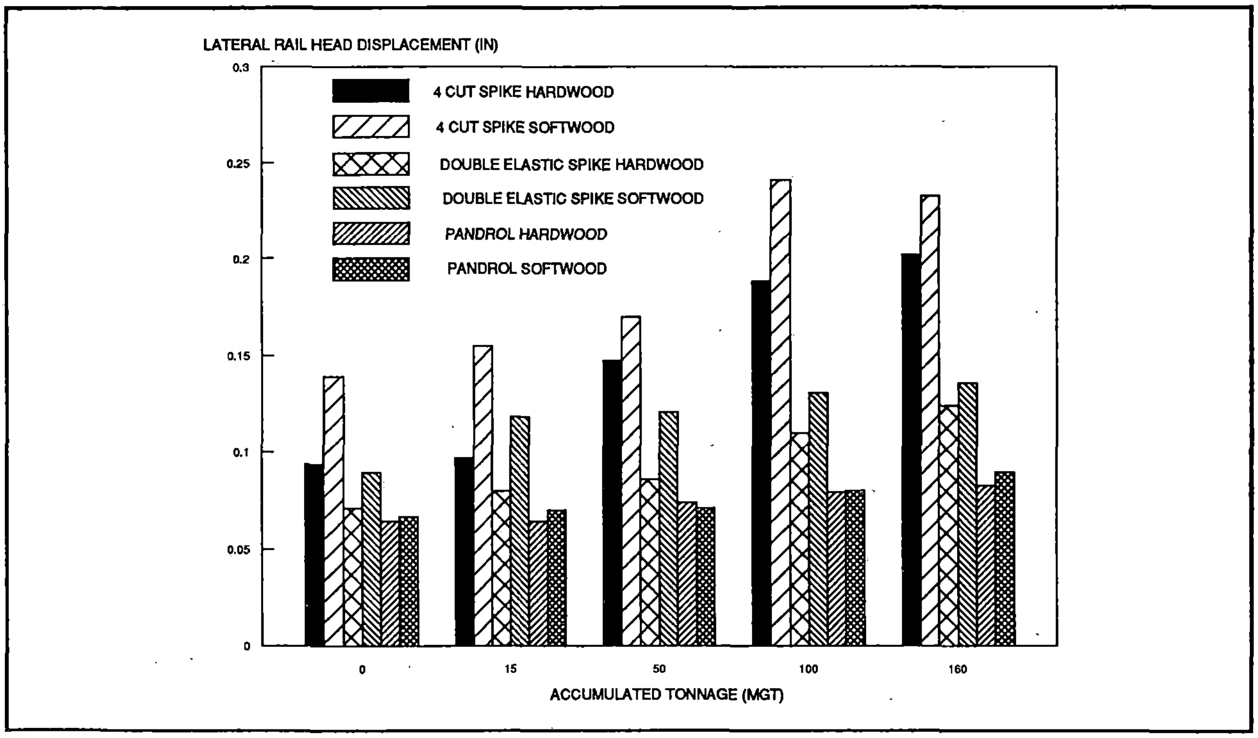

Figure 22. Comparison of the Average Lateral Railhead Displacement Measured on Hardwood and Softwood Ties in Section 07 at 160 MGT

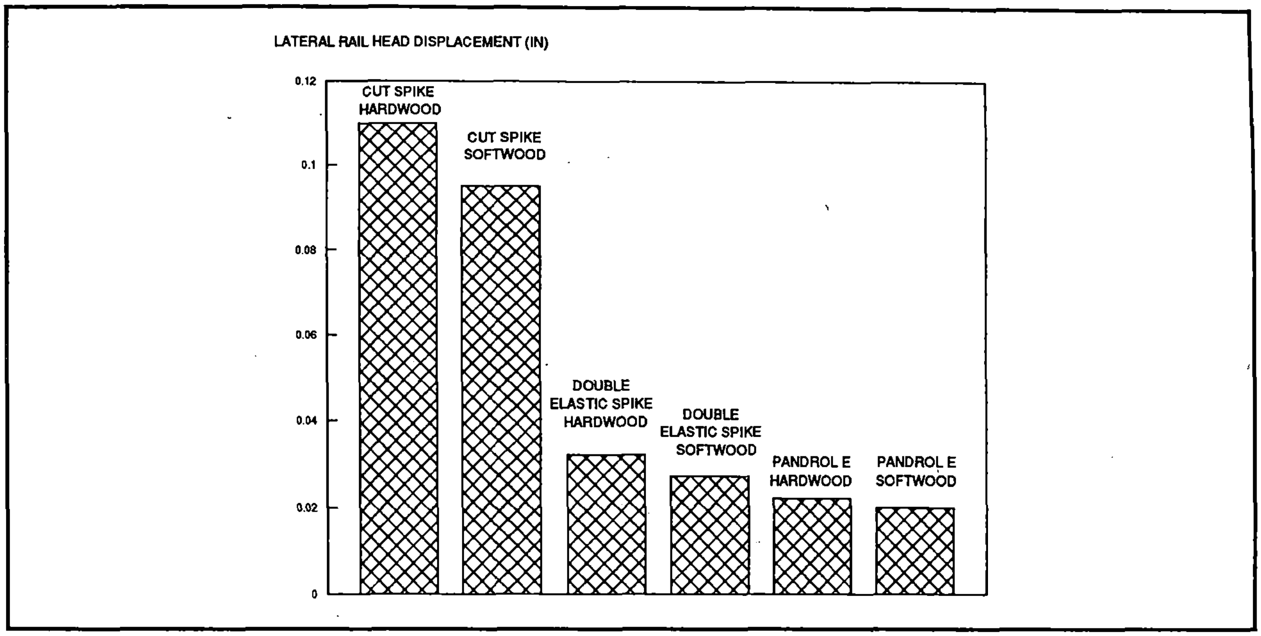

Figure 23. Comparison of Lateral Railhead Displacement Increase Over Time Allowed by Hardwood and Softwood Ties in Section 07

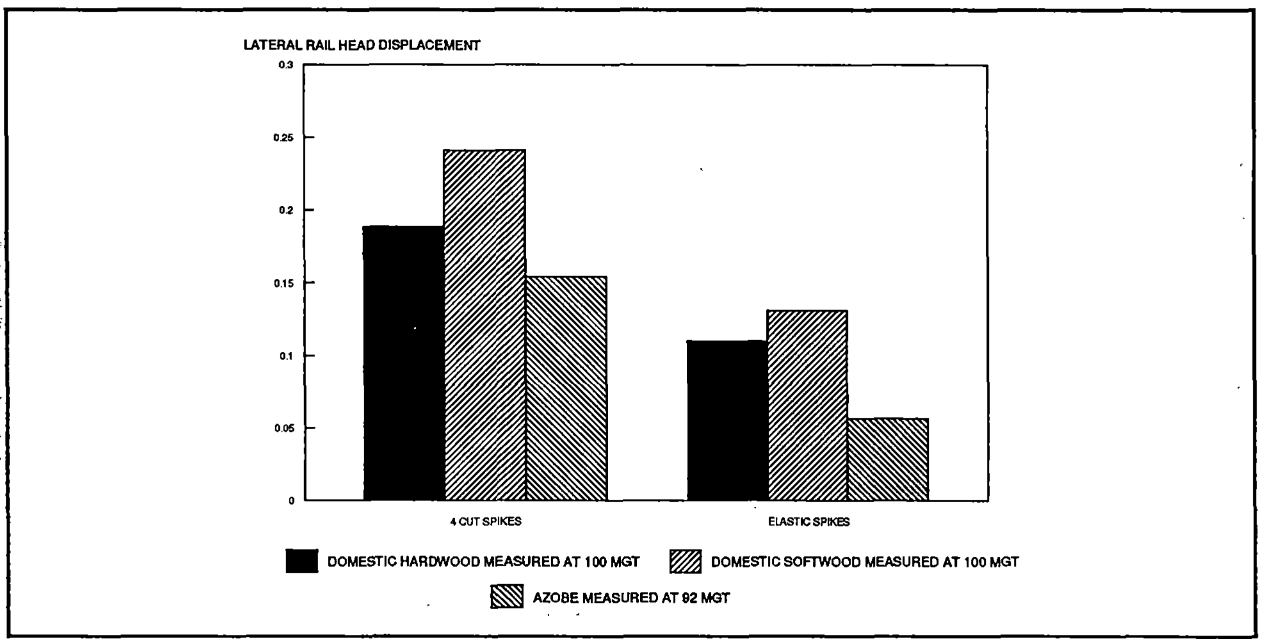

Figure 24. Comparison of Lateral Railhead Displacement Measured on Azobe and Domestic Hardwood/Softwood Ties

4.2 DYNAMIC RAILHEAD DISPLACEMENT

Lateral displacement of the railhead under dynamic forces of the HAL train was measured at 5 MGT and 80 MGT in Section 07. Distribution of the 80 MGT displacement data for the cut spike, elastic spike, and Pandrol fasteners in Section 07 is shown in Figure 25 (the McKay data was omitted due to instrumentation problems). Each curve is the combined distribution of peak displacements generated by each wheel in the consist (locomotive data has been deleted) at two high and two low rail locations per fastener type. The data was collected with the train operating at 40 mph and represents 33 passes of the consist at each measurement location.

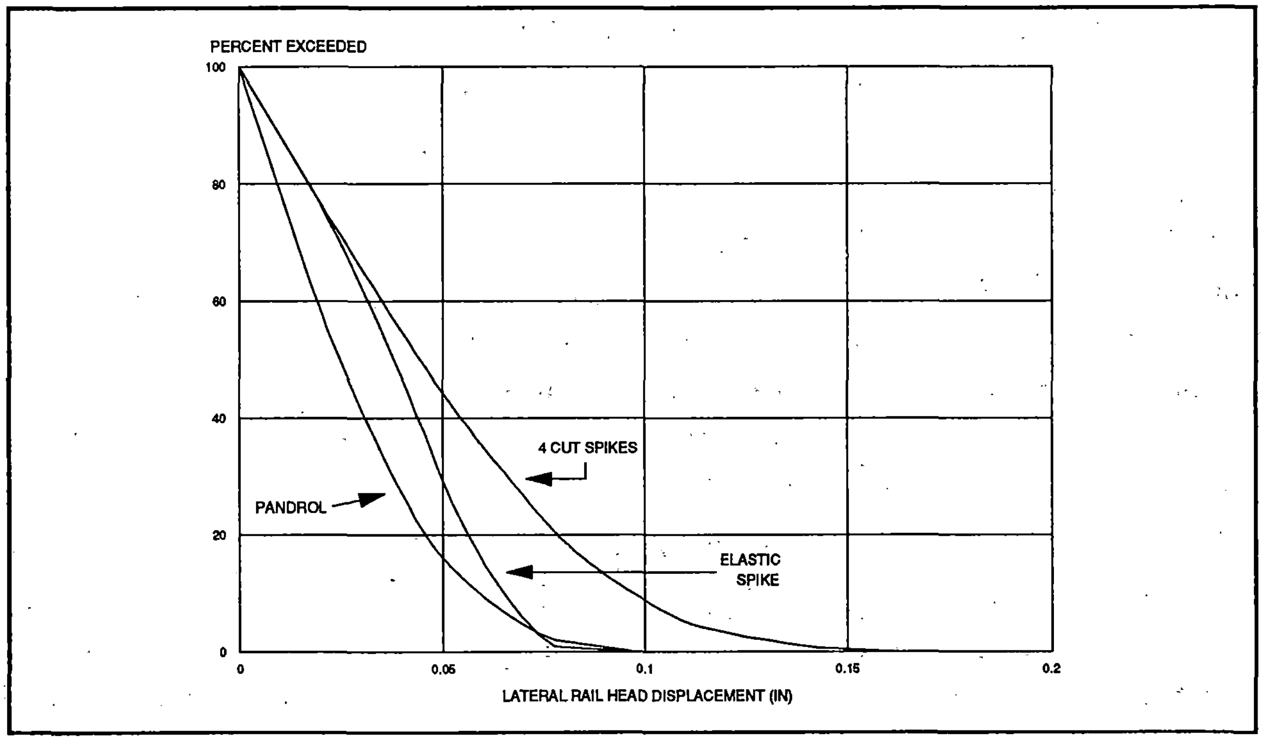

Figure 25. Distribution of Peak Railhead Displacements Measured Under the HAL Train at 40 MPH in Section 07

The distributions indicate lateral railhead displacements on ties with cut spikes are significantly higher than displacements on ties with elastic fasteners for about 30 percent of the wheel passes. However, the 2:1 difference in cut spike and elastic fastener displacements measured under static forces was not seen in the dynamic data.

Long term fastener performance can be quantified by tabulating component failures and the labor hours required to maintain the system. Clip failures were limited to the Koppers fastener in Section 07. During the initial 15 MGT, 23 failures out of a population of 80 fasteners, all due to loss of toe load, were observed in the softwood ties of the Koppers subsection. This led to fasteners being removed from the softwood ties at the 15 MGT point. Koppers fasteners on the hardwood ties remained in service during the 160 MGT period with 10 failures, including two fractured clips, recorded out of a population of 320 fasteners. The typical failure mode on both hardwood and softwood ties was loss of toe load caused by the backing out of the U-shaped staple which served as the reaction device for the clip toe load. Because it is no longer available as a fastening system, the decision was made to remove the Koppers fasteners on hardwood ties at 160 MGT. There were no other failures recorded for any of the other fastener types, nor was there any maintenance required by any fastener other than the Koppers during the 160 MGT period.

5.0 TIE PLATE CUTTING

Tie plate cutting is a mode of tie failure which is directly influenced by vertical wheel loading and, therefore, can be considered a key indicator of tie performance under 39-ton axle load traffic. The tie plate cutting measurement fixture is aligned to indexing holes located at each corner of the tie plate and the change in tie plate height relative to the tie surface is measured with dial indicators with stems that rest on lag screws that have been glued into the tie as shown in Figure 26.

The average tie plate cutting depth for 7x9 inch and 6x8 inch ties with four cut spikes per plate in Section 27 is shown in Figure 27. The chart shows the total cutting at 160 MGT and the difference in the cutting depth between hardwood and softwood ties. Data in the chart indicates that the softwood ties are showing the most plate cutting, primarily on the field side of the low rail. The negative value shown for the 7x9 inch softwood ties indicates plates are lifting slightly from the tie surface on the gage side of the low rail when the rail is not under load.

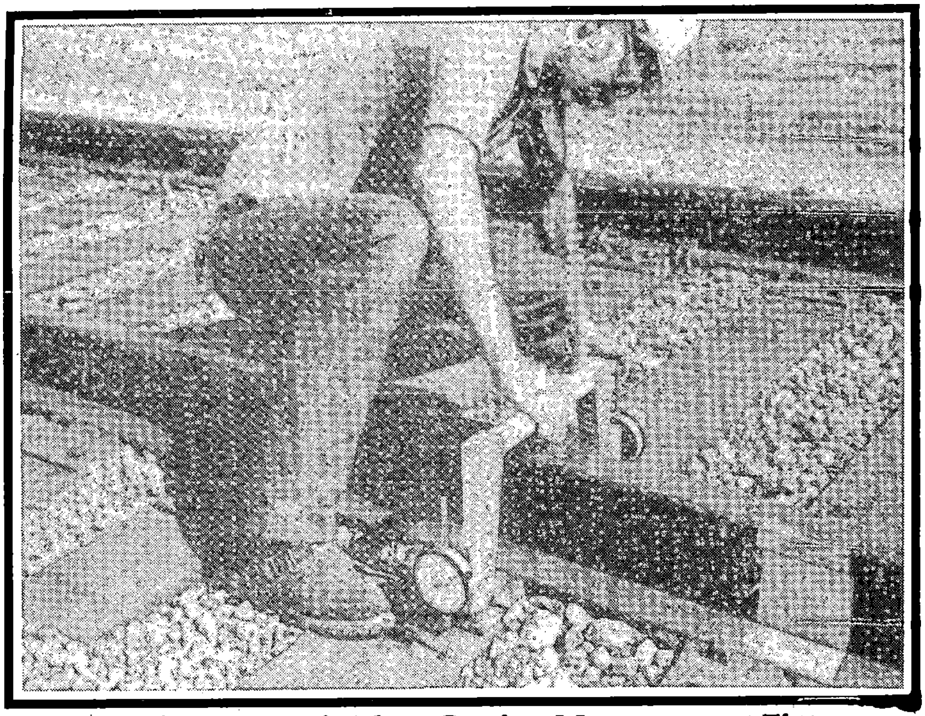

Figure 26. Tie Plate Cutting Measurement Fixture

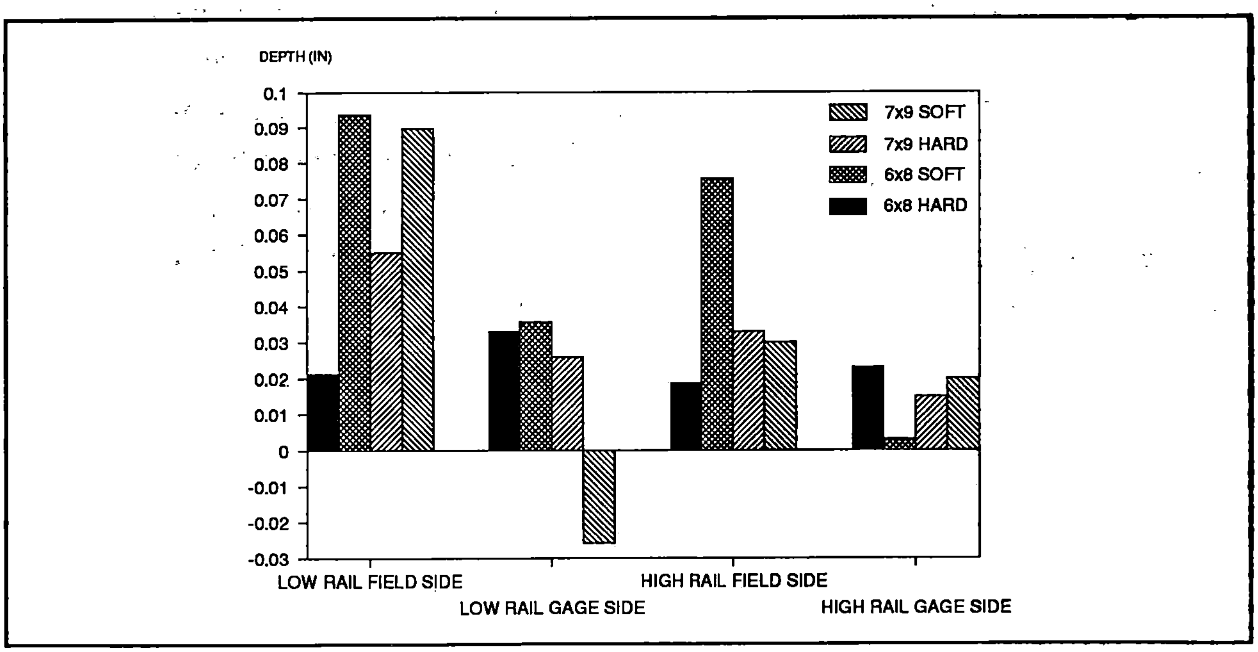

Figure 27. Average Tie Plate Cutting Depth on Hardwood and Softwood Ties in Section 25 after 160 MGT

6.0 OBSERVED TIE AND FASTENER BEHAVIOR

Visual observations of tie and fastener performance outside the measured parameters are summarized as follows:

1. There was no visual evidence of significant tie splitting in the test zones. The hardwood ties were equipped with anti-spitting devices but the softwood and Azobe ties were not. The Azobe ties installed at 100 MGT have shown signs of checking on the top surface.

2. Tie skewing was evident in the double elastic spike subsection of Section 07 and in the Azobe subsection with double elastic spikes spaced on 24-inch centers in Section 31. The skewing, in neither case, affected track geometry or stability.

3. In the cut spike subsections, excluding the Azobe ties, longitudinal movement of the rail and anchored ties through the ballast section was observed during the initial 25 MGT of operation. The movement was noted in all curves and spirals of the HTL and was not a failure of the rail anchors but of the ballast in the tie cribs. By anchoring every tie, rather than every other tie, longitudinal rail forces were transmitted to the ballast section through twice the number of anchored ties and the movement ceased. Longitudinal movement of the track panel (track skeleton) was not observed in any of the elastic fastener subsections.

7.0 CONCLUSIONS

Conclusions of the Wood Tie and Fastener Experiment after accumulation of 160 MGT of HAL traffic are as follows:

1. Under comparable static vertical and lateral forces, higher rail base displacement and rail rotation values have been measured during the HAL program than were measured during the third wood tie and fastener test of the 33-ton axle load program.[3] Comparing only the softwood cut spike subsections in Section 07, average rail rotation values in particular are significantly higher, showing a 70 percent to 100 percent increase at L/V ratios of 0.35 to 0.5. It should be noted, however, that the ties used during the 33-ton axle load program were southern yellow pine,[4] whereas, the HAL softwood ties were fir. Further fastener comparison was not possible due to lack of common types between the programs.

2. Under static vertical and lateral forces equivalent to a L/V ratio of 0.5, the cut spike allows at least twice the lateral railhead displacement, rail rotation, and gage widening of any of the elastic fasteners being tested. At L/V ratios less than 0.25, there is no measurable difference in the lateral restraint capabilities of any of the fastener types, including the cut spike. These results agree with those of wood tie fastener testing conducted during the 33-ton axle load phase of the FAST program.[3]

3. The rate of lateral rail restraint degradation was four to five times higher for the cut spikes compared to the elastic fasteners. Lateral restraint degradation is defined as the increase with traffic in the average lateral railhead displacement under a static load of 40 kips vertical and 20 kips lateral. After 160 MGT, the displacement at the cut spikes had increased 0.120-inches where the elastic fasteners had increased 0.017-inches to 0.022-inches.

4. The cut spike system shows approximately 30 percent more railhead displacement on softwood ties than on hardwood ties. The double elastic spike shows 10 percent more displacement on

the softwood ties as compared to the hardwood ties. The Pandrol system shows no difference in rail displacement between hardwood ties and softwood ties. Although cut and elastic spikes allow more lateral rail displacement on softwood ties than on hardwood ties, the loss of lateral rail restraint with tonnage accumulation is about the same for both kinds types of wood for all fastener types compared.

5. The Koppers fastener exhibited a tendency to lose toe load under traffic, particularly on softwood ties, resulting in removal of the system after 15 MGT. None of the other fastener types recorded any fastener failures or required maintenance during the test period. Despite the increased displacement and rotation values measured, fastener performance in terms of failures and required maintenance during the HAL program is considerably less than the documented performance during the 33-ton program.[4] Once again, the reader is reminded that the cut and double elastic spikes are the only fastener types common to the two programs.

6. There is no significant difference in the measured and observed performance of the four and five cut spike systems.

7. Lateral railhead displacement measured on Azobe ties with cut and elastic spikes at 92 MGT is consistently less than displacements measured on domestic hardwood ties and softwood ties with similar fasteners at 100 MGT. In both cases, the displacements were measured under static forces equivalent to an L/V ratio of 0.5.

8. Tie plate cutting is occurring primarily on the field side of the low rail on the softwood ties in Section 25. The cutting is causing the cant of the rail to decrease. The 6x8 inch softwood ties show the most field side cutting on both high and low rails; however, the 6x8 inch hardwood ties show the least amount of field side cutting of the ties in the section. The least amount of cutting for any tie type is occurring on the gage side of the high rail. Comparison of tie plate cutting rates with the 33-ton program is difficult since

the type of cutting seems to be entirely different. Data from the 33-ton axle load program indicated that most of the cutting was vertical and the differential cutting was on the gage side of the high rail which is opposite the HAL experience.[3] It does appear that the vertical cutting of the low rail plates on softwood ties (0.02 - 0.03 inches) is about the same as the vertical cutting reported during the 33-ton phase.

9. None of the wood tie test zones showed any significant degradation in track geometry. Other than repair of a track buckle in Section 07 at 45 MGT,[5] neither of the original test zones in Sections 07 or 25 was surfaced or lined during the initial 160 MGT of HAL operation.

PART II: CONCRETE TIE AND FASTENER EXPERIMENT

1.0 INTRODUCTION AND OBJECTIVE

At the beginning of the HAL program, donations of concrete ties, insulators, tie pads, and rail fasteners were received from Burlington Northern Railroad Company (BN 100), Canadian National Railways (CN 60C), AMTRAK, and the Koppers Corporation and were installed in the 5-degree curve of Section 03. Two tie types were subsequently added to the experiment. The CN 60D tie, a slightly smaller tie designed for tangent track applications, was installed after 15 MGT of HAL traffic in Section 33. The other tie, a post-tensioned design, manufactured by ITISA of Mexico, was installed in the 5-degree curve of Section 31 at 70 MGT.

Concrete ties installed during the 33-ton axle load program were also included in the FAST High Tonnage Loop (HTL), but not as test components. Ties (Santa Fe Pomeroy RT-7SS) which had been part of the original concrete tie experiment at FAST and subjected to 1,100 MGT of 33-ton axle load traffic prior to initiation of the HAL program, were installed at both ends of the concrete tie test zone in Section 03 to serve as transitions to the surrounding wood ties. Another set of ties, installed in 1979 as part of the Northeast Corridor Correlation study and which had accumulated about 700 MGT of 33-ton axle load tonnage, was installed in the spiral between the CN 60D tangent ties and the ITISA post-tensioned ties (Figure 1).

2.0 DESCRIPTION OF THE TEST ZONES AND COMPONENTS

The concrete tie test zone in Section 03 is approximately 1,154 feet long. The zone is made up of 25 RT-7SS ties (original FAST ties) at both ends, which serve as transitions to the surrounding wood ties, 79 BN-100 ties, 98 Koppers ties, 79 CN 60C ties, 121 AMTRAK ties, and 175 ties under proprietary testing (Figure 2). The ballast in the test zone is a mixture of granite and quartzite material that was installed in 1979. Average depth of ballast beneath the low rail was 18 inches with the high rail elevated 4 inches.[6] High rail ballast shoulder width was 15-18 inches and 1.5:1 slope. Rail in the zone was 136-pound continuous welded rail (CWR) with irregularly occurring joints. The high rail was changed at 15 MGT into the HAL program, and part of the low rail was changed at 70 MGT.

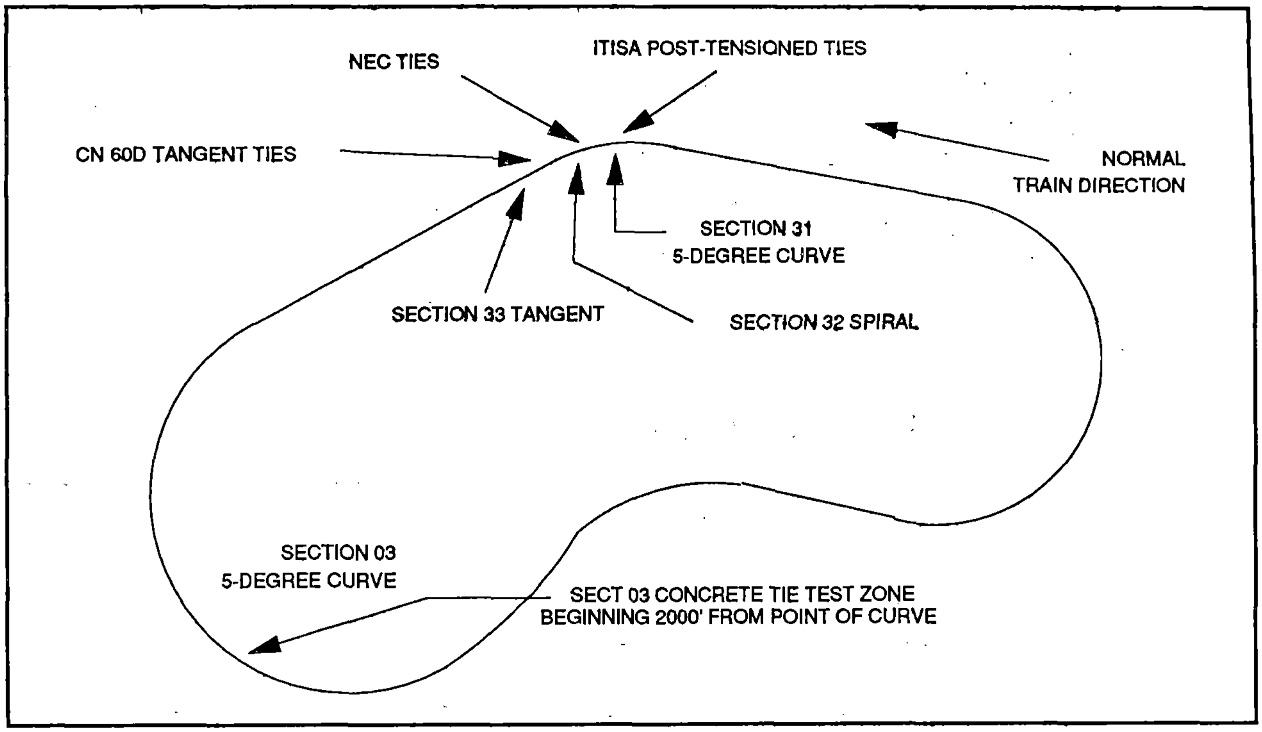

Figure 1. Location of Concrete Tie Test Zones on the High Tonnage Loop

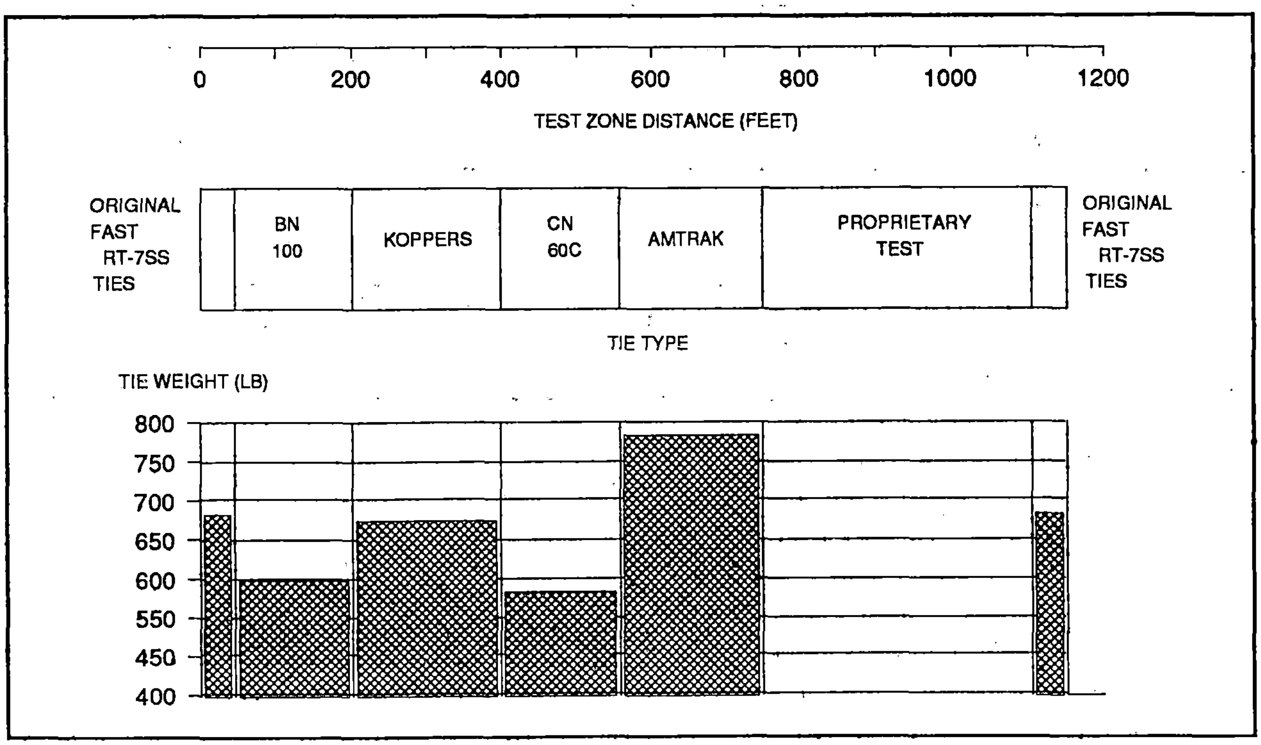

Figure 2. Layout of Section 03 Concrete Tie Test Zone

Fifty CN 60D ties were installed in the tangent track of Section 33 and 100 ITISA post-tensioned ties were installed in the 5-degree curve of Section 31. Section 33 was constructed of traprock ballast and 136-pound CWR, while Section 31 had 133-pound CWR and granite ballast. The ballast section in Sections 31 and 33 had 12 inches below tie depth and 12-15 inch shoulders. As in Section 03, the design superelevation for Section 31 was 4 inches. All concrete ties were spaced on 24-inch centers.

Table 1 lists the rail fastening systems used on the various ties.

Table 1. Description of Concrete Tie Rail Fastening Systems

TIE TYPE	FASTENER TYPE	PAD TYPE	INSULATOR TYPE
BN 100	McKay	EVA	McKay Maranyl
CN 60C	Pandrol 601A	EVA	Pandrol HD-8
Koppers	Pandrol E	1/2 zone EVA 1/2 zone Rubber	1/2 Zone Pandrol HD-10 1/4 Zone Pandrol P-10 1/4 Zone Pandrol H8 GN1
AMTRAK	Pandrol E	EVA	Pandrol 4277
CN 60D	Pandrol E	10 mm Rubber	Pandrol HD-8
ITISA	Pandrol E	7 mm Polyurethane	Pandrol HD-10

All ties were installed using the same basic procedure: about 6 inches of ballast was removed beneath existing ties using a Canron Track-Gopher, the ties were removed, and the concrete test ties installed under existing rail. The track was re-ballasted and brought to final profile and alignment. The zone in Section 03 was surfaced at 15 MGT and 70 MGT to restore superelevation. Section 31 and 33 zones required no maintenance.

3.0 DYNAMIC WHEEL/RAIL FORCES

Instrumented rail (wayside) and instrumented wheel set (vehicle borne) measurement systems were used to characterize vertical and lateral wheel/rail forces in the concrete tie zones at 100 MGT. Wayside rail force data was collected with rail mounted strain gage instrumentation designed to measure vertical and lateral forces.[7] Each strain gage circuit was calibrated in the track using the TTC Rail Force Calibration Car (605 car). The vertical circuits were calibrated to a maximum force of 40,000 pounds and the lateral circuits to 20,000 pounds while under the maximum vertical force.

Wayside data was post processed to determine peak vertical and lateral force values of each wheel crossing each circuit. Distributions of peak vertical and lateral rail forces generated by the HAL train, excluding locomotives, measured at a single (high and low rail) wayside location about midway into the BN 100 tie subsection are shown in Figures 3 and 4 respectively. The distributions represent data from 25 consecutive passes of the train and are plotted as percentages of the total force population exceeding a given load value.

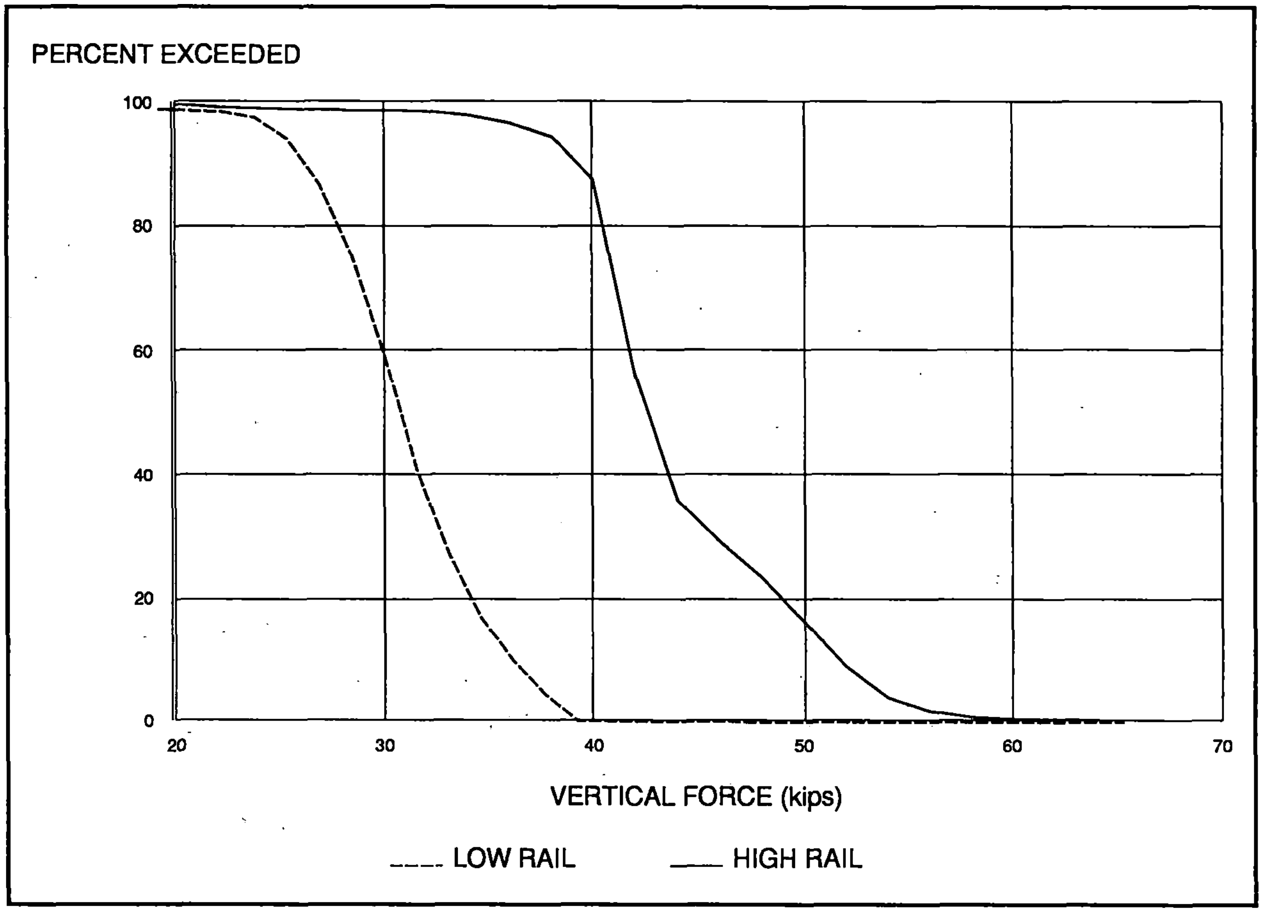

Figure 3. Wayside Vertical Rail Force Distribution Section 03 Concrete Tie Zone

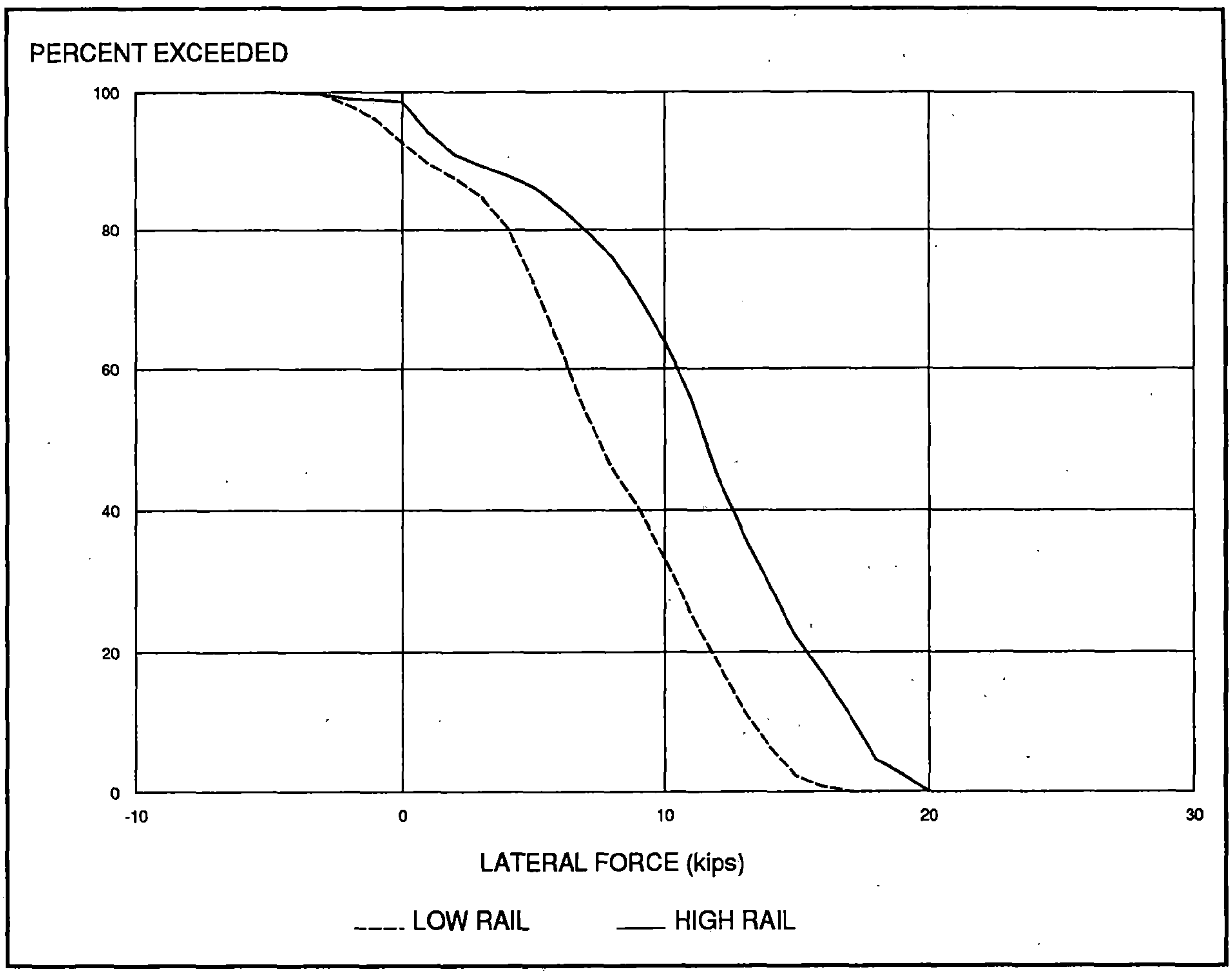

Figure 4. Wayside Lead Axle Lateral Rail Force Distribution For the Section 03 Concrete Tie Zone

By capturing forces generated by every wheel in the train, wayside force measurements are used to define the force spectrum. However, since the instrumentation is confined to a discrete point along the track, the values measured can be influenced by track irregularities and vehicle dynamics. The force distributions in Figures 3 and 4 are included to give an idea of the typical range of forces generated by the HAL train in the Section 03 zone. To complement the wayside data, continuous wheel force data as measured with an instrumented wheel set is also included.

A pair of 38-inch instrumented wheel sets were installed under a 39-ton axle load car from the HAL consist to acquire continuous wheel force data. The wheel sets contained standard 38-inch curved plate wheels with instrumentation similar in design to that described in the publication listed in reference 8. Time history plots of continuous vertical and lateral wheel forces recorded at 40 mph in the Section 03 test zone are shown in Figures 5, 6, and 7. The data was collected with an instrumented wheel set positioned as the leading axle of the lead truck, and the data represents one pass of the vehicle through the zone at 40 mph.

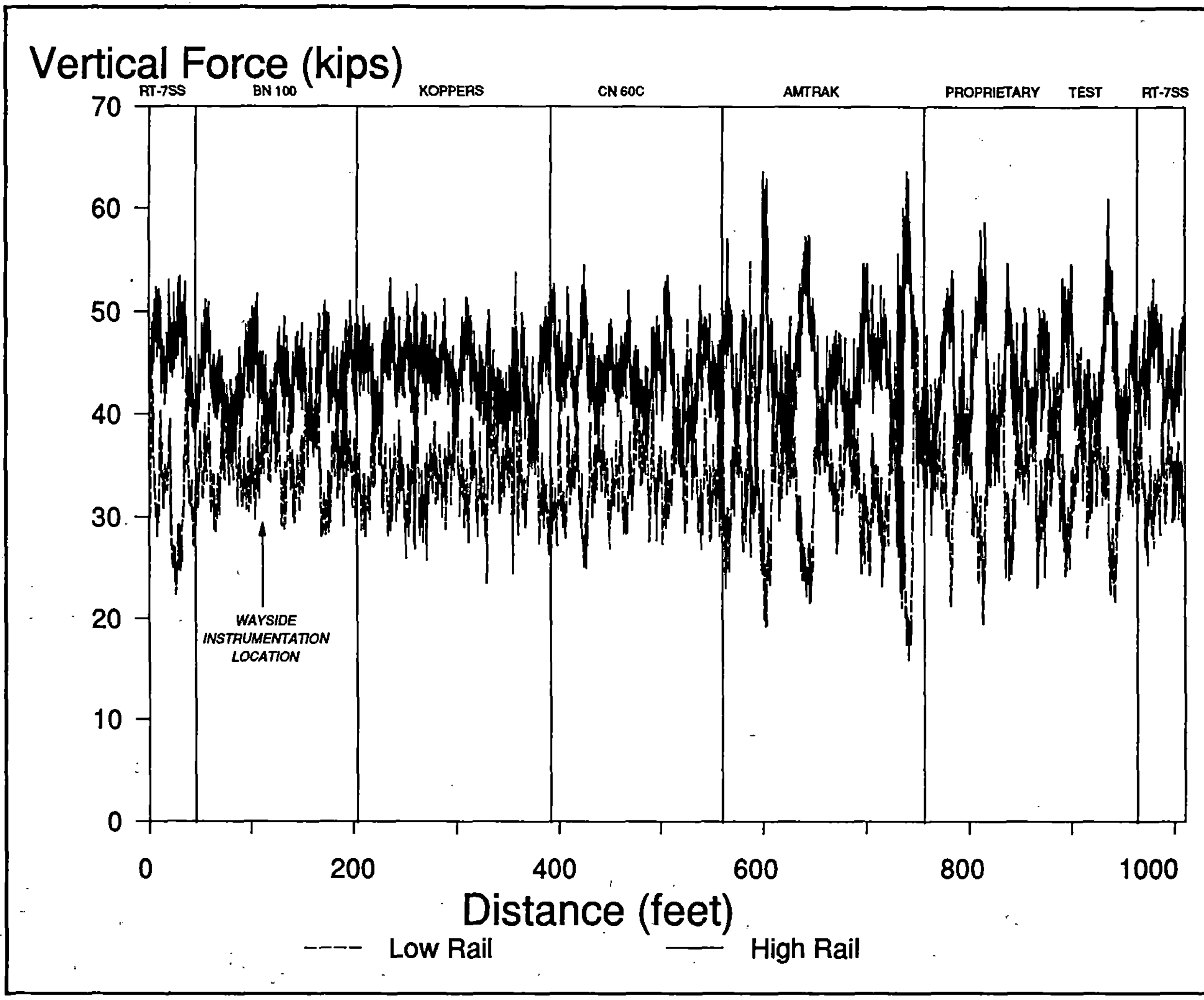

Figure 5. Lead Axle Vertical Wheel Force Data For Section 03 Concrete Tie Zone

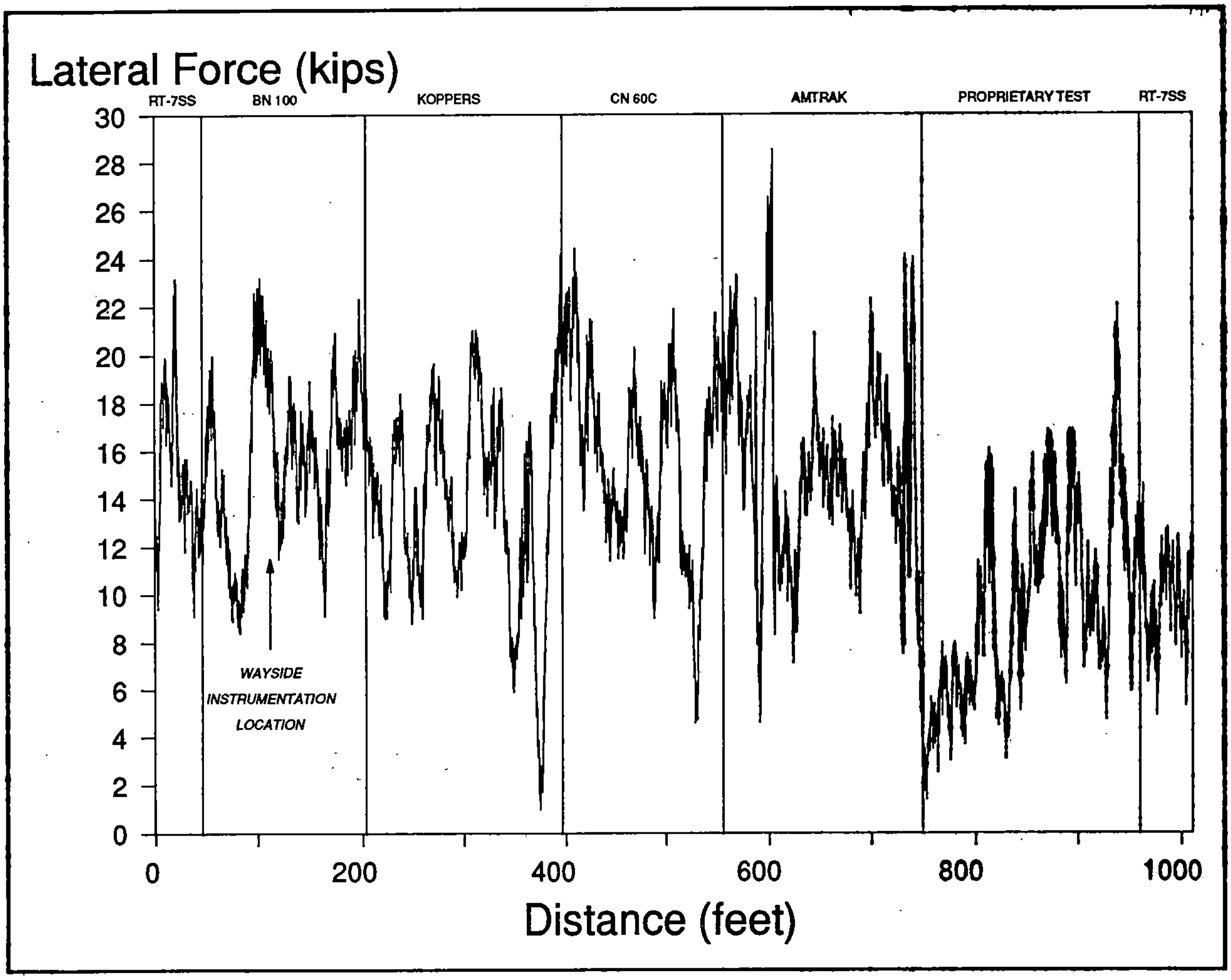

Figure 6. Lead Axle Lateral Wheel Force Data For Section 03 Concrete Tie Zone High Rail

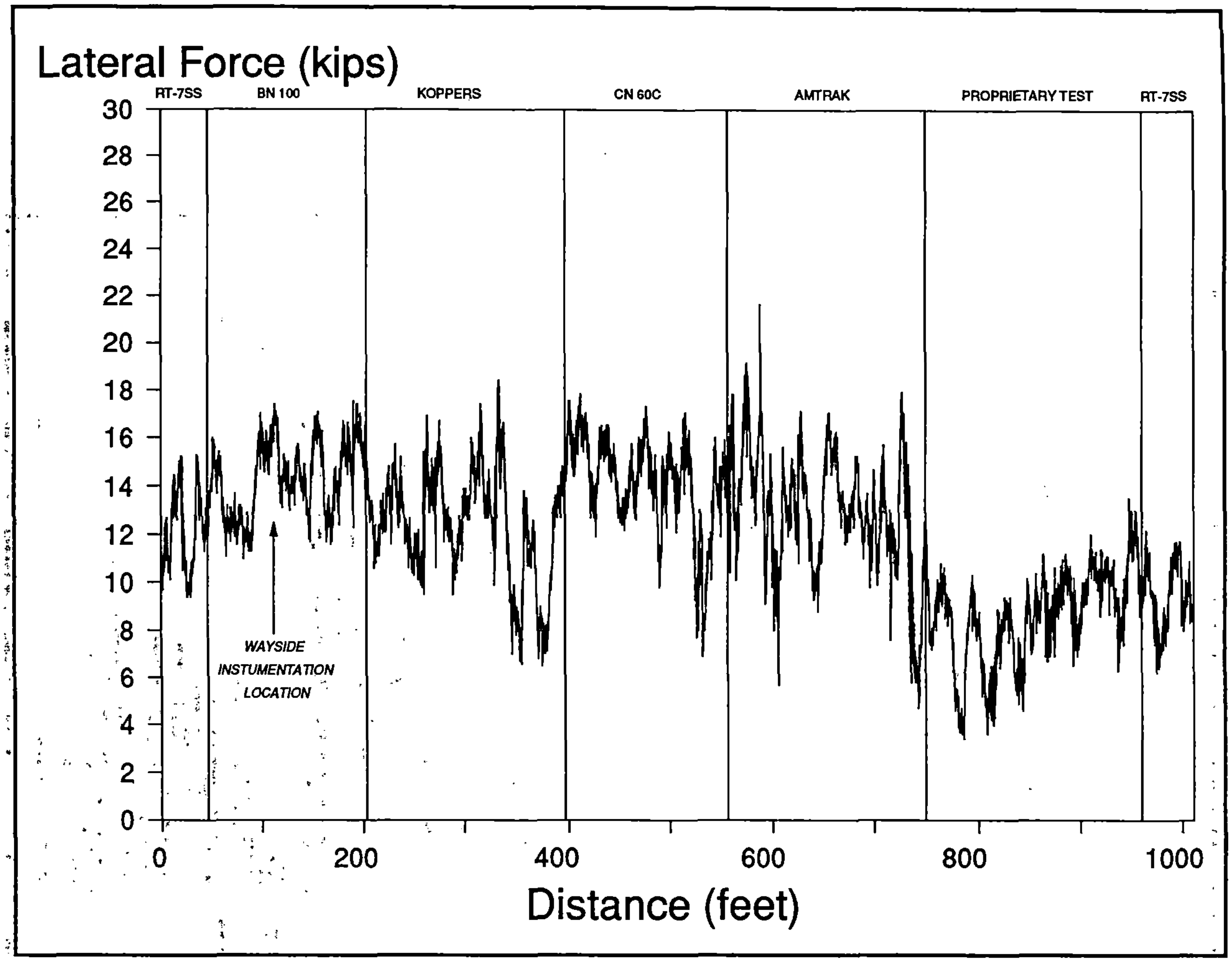

Figure 7. Lead Axle Lateral Wheel Force Data For Section 03 Concrete Tie Zone Low Rail

The average and maximum vertical and lateral wheel forces measured in each concrete tie subsection are listed in Table 2. The statistics were computed from data collected during one pass of the instrumented wheel set through the test zones at 40 mph. The average vertical and lateral force values in Table 2 are typical of data measured at other HTL curve sites.[9] Section 03 high rail maximum lateral forces listed in Table 2 and dynamics shown in Figure 6, however, are higher and more pronounced than would be expected. The primary cause of the somewhat extreme lateral force behavior measured in the Section 03 zone was the accumulation of bolted joints, field welds, and short plug rails from numerous broken rail repairs.

Table 2. Average and Maximum Wheel Force Values For Concrete Tie Test Zones

	BN 100		KOPPERS		CN 60C		AMTRAK		ITISA		CN 60D	
LEAD AXLE WHEEL FORCE (KIPS)	LOW RAIL	HIGH RAIL	LOW RAIL	HIGH RAIL	LOW RAIL	HIGH RAIL	LOW RAIL	HIGH RAIL	LOW RAIL	HIGH RAIL	IN-SIDE RAIL*	OUT-SIDE RAIL *
Average Vertical	34	42	34	42	34	43	33	43	36	44	42	40
Maximum Vertical	44	52	41	53	42	56	55	64	48	60	52	59
Average Lateral	13.2	15.2	12.9	13.2	13.0	14.1	13.7	14.3	7.2	9.6	0.8	1.2
Maximum Lateral	17.1	23.5	17.9	23.8	17.6	24.5	21.6	28.3	14.7	17.6	2.2	2.7

* Tangent zone -- inside/outside rail of the loop

4.0 DYNAMIC TIE STRAINS

To determine dynamic strain response to 33- and 39-ton axle loads, axial strains were measured on the top surfaces of three consecutive BN 100 ties. Single element strain gages were installed at five locations along the longitudinal axis of each tie and were labeled SG01-SG05 (Figure 8). Strain data was collected at each tie and strain gage location during 32 passes of a train with equal numbers of 33- and 39-ton axle load cars. Train speed was 40 mph and the output of each strain gage was recorded digitally at a sample rate of 3,000 samples-per-second.

Distributions of strains above 100 microstrain were computed for each strain gage position. Comparisons of the distributions for 33- and 39-ton axle load cars are shown in Figures 9-14. The plots show that the lowest strains were recorded furthest from the tie center at the SG01 and SG05 positions, while the highest strains were at the SG02, SG03, and SG04 positions. All strains recorded were tensile, indicating negative bending of the tie between the rail seats as expected. No compressive strains were measured at any location.

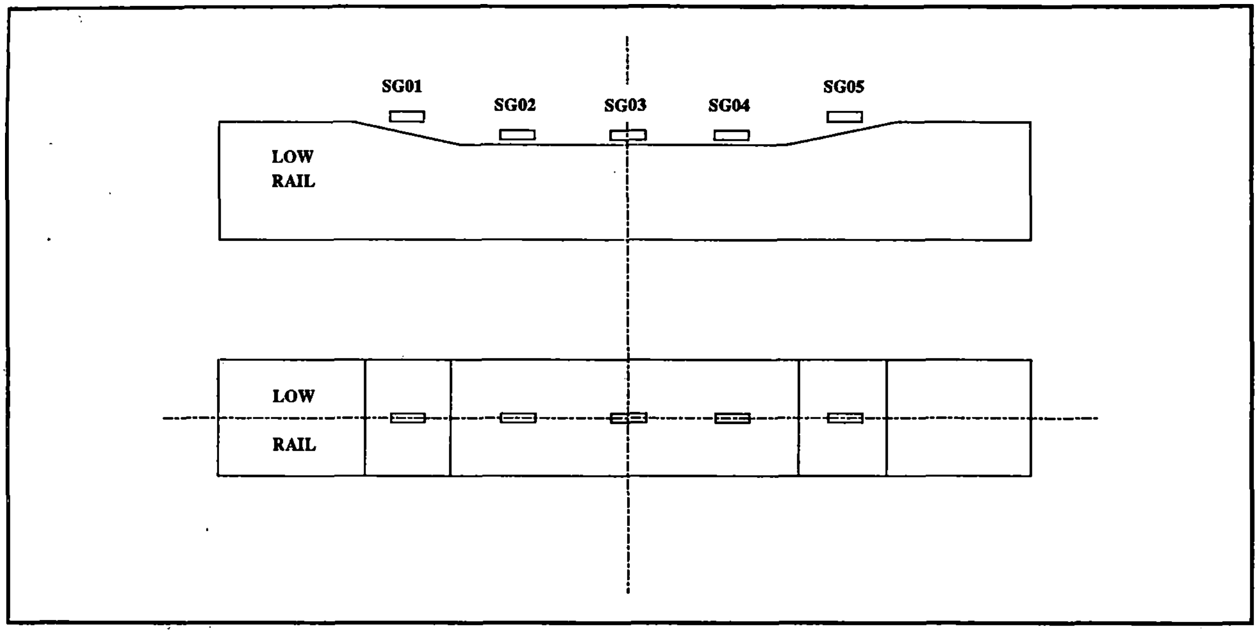

Figure 8. Position of Strain Gages on Instrumented Ties

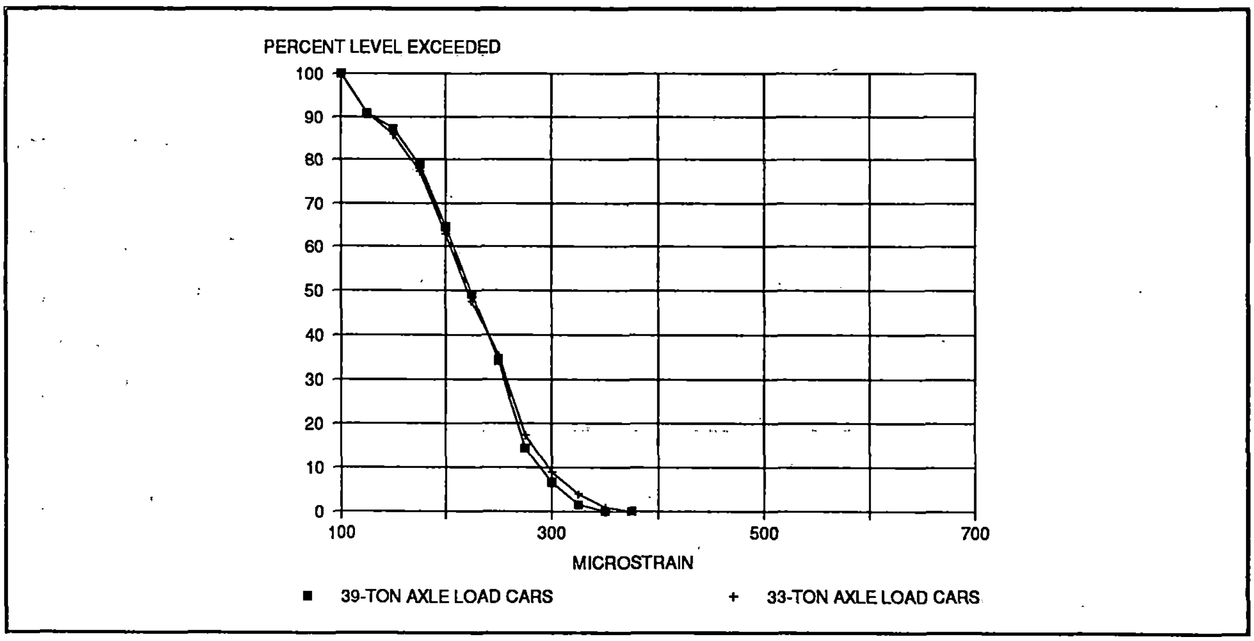

Figure 9. Comparison of Dynamic Strain Distributions at the SG01 Location

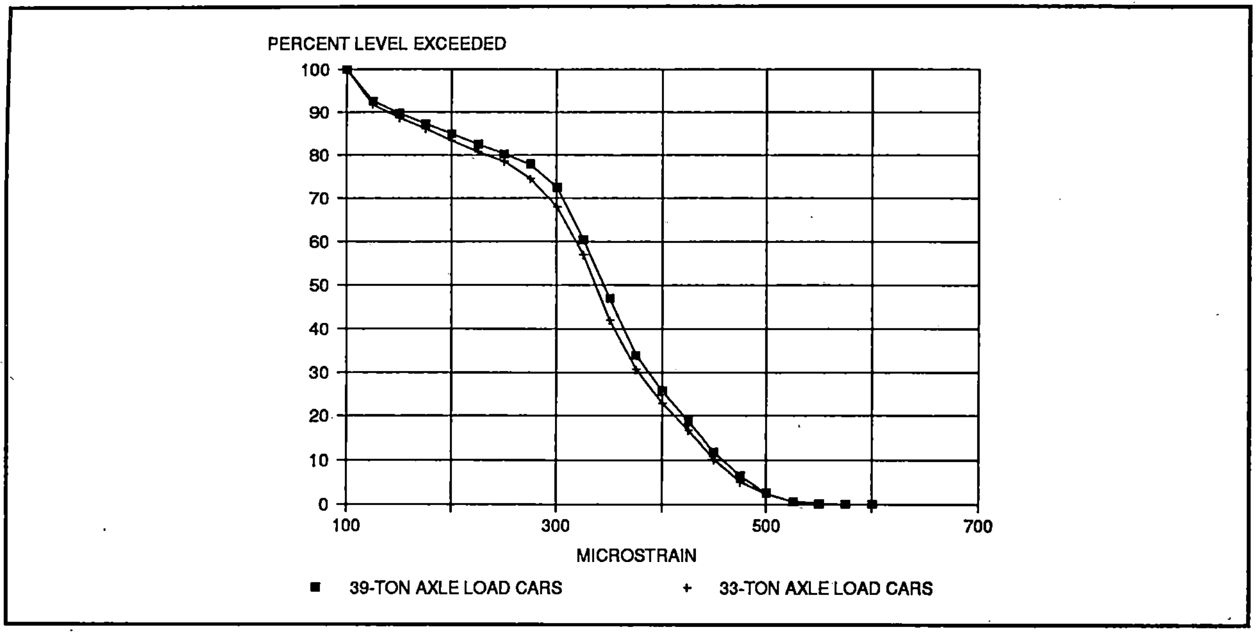

Figure 10. Comparison of Dynamic Strain Distributions at the SG02 Location

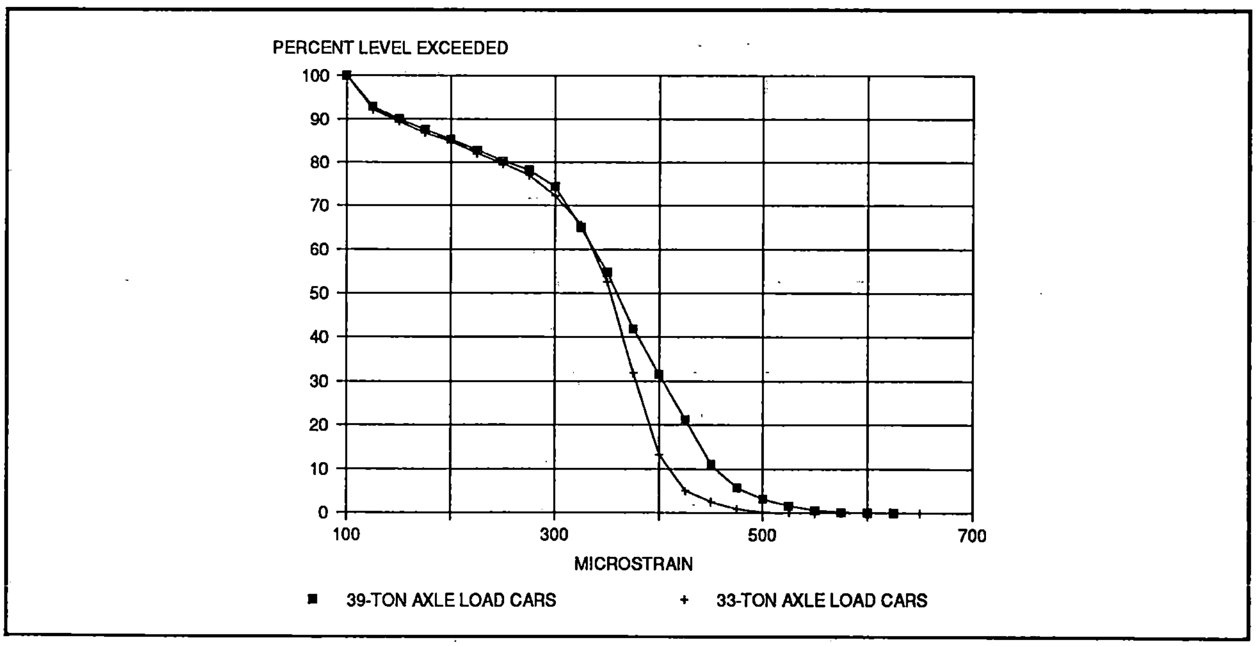

Figure 11. Comparison of Dynamic Strain Distributions at the SG03 Location

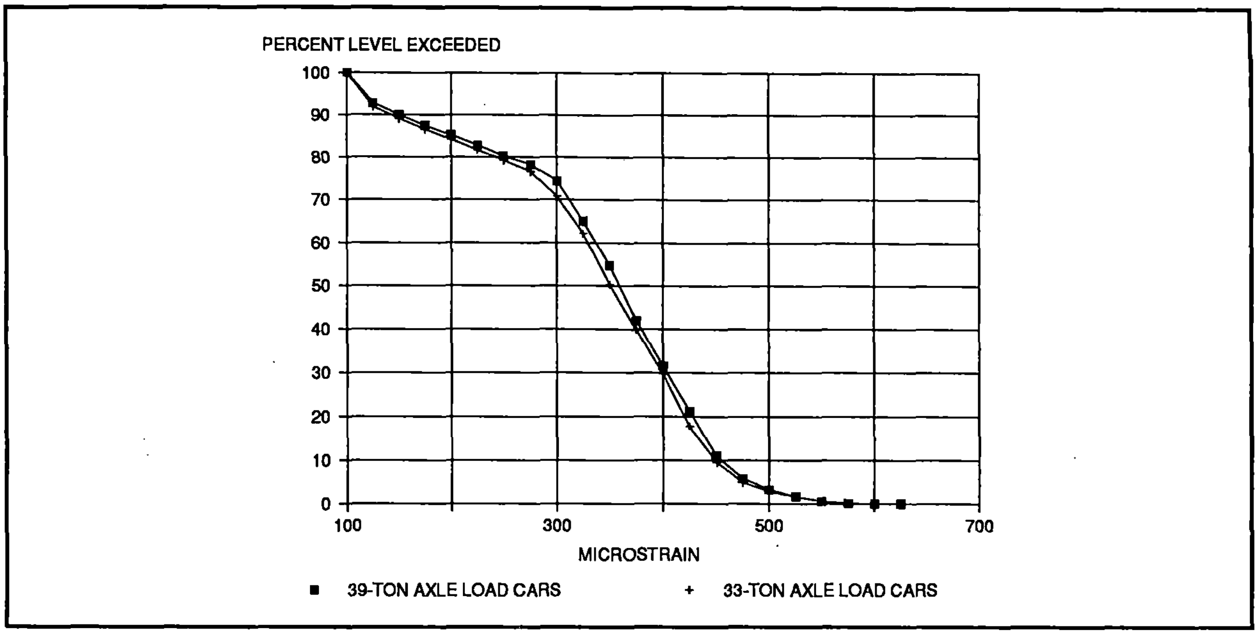

Figure 12. Comparison of Dynamic Strain Distributions at the SG04 Location

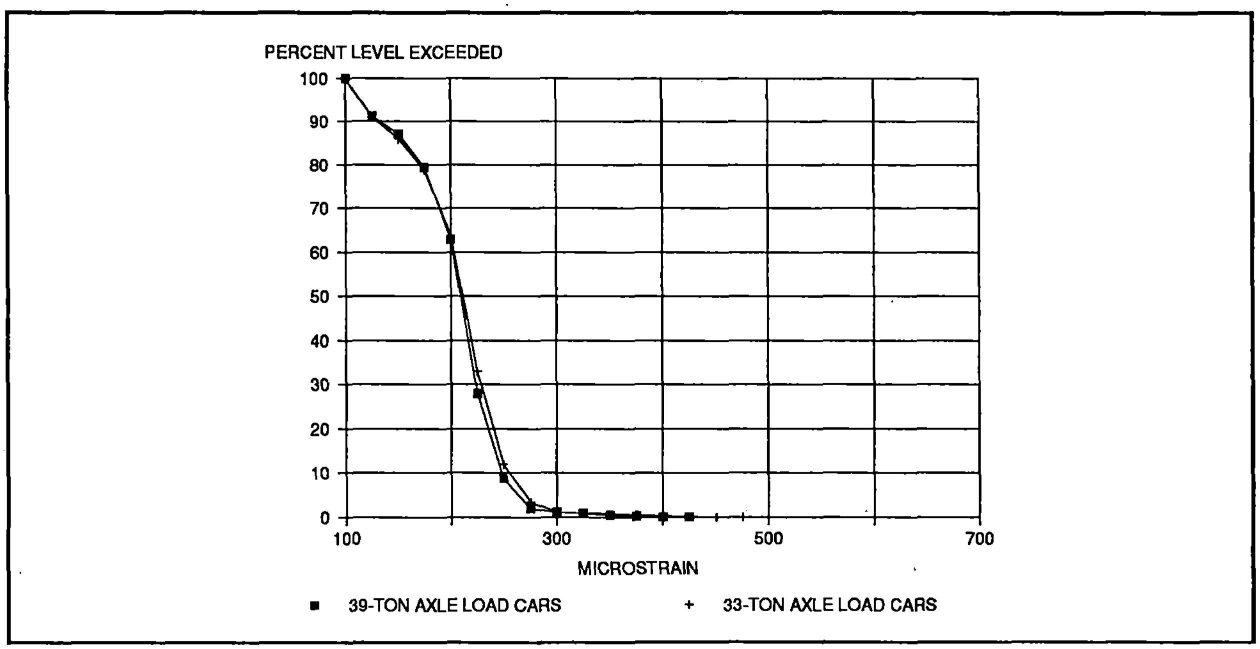

Figure 13. Comparison of Dynamic Strain Distributions at the SG05 Location

In Figure 14, a comparison of the 95th percentile strain values by axle load is plotted for each strain gage location. The greatest differential occurred at the SG03 strain gage position where the 39-ton axle load vehicles produced strains 13 percent higher than the 33-ton axle load cars. Little difference in strain by axle load was measured at other positions.

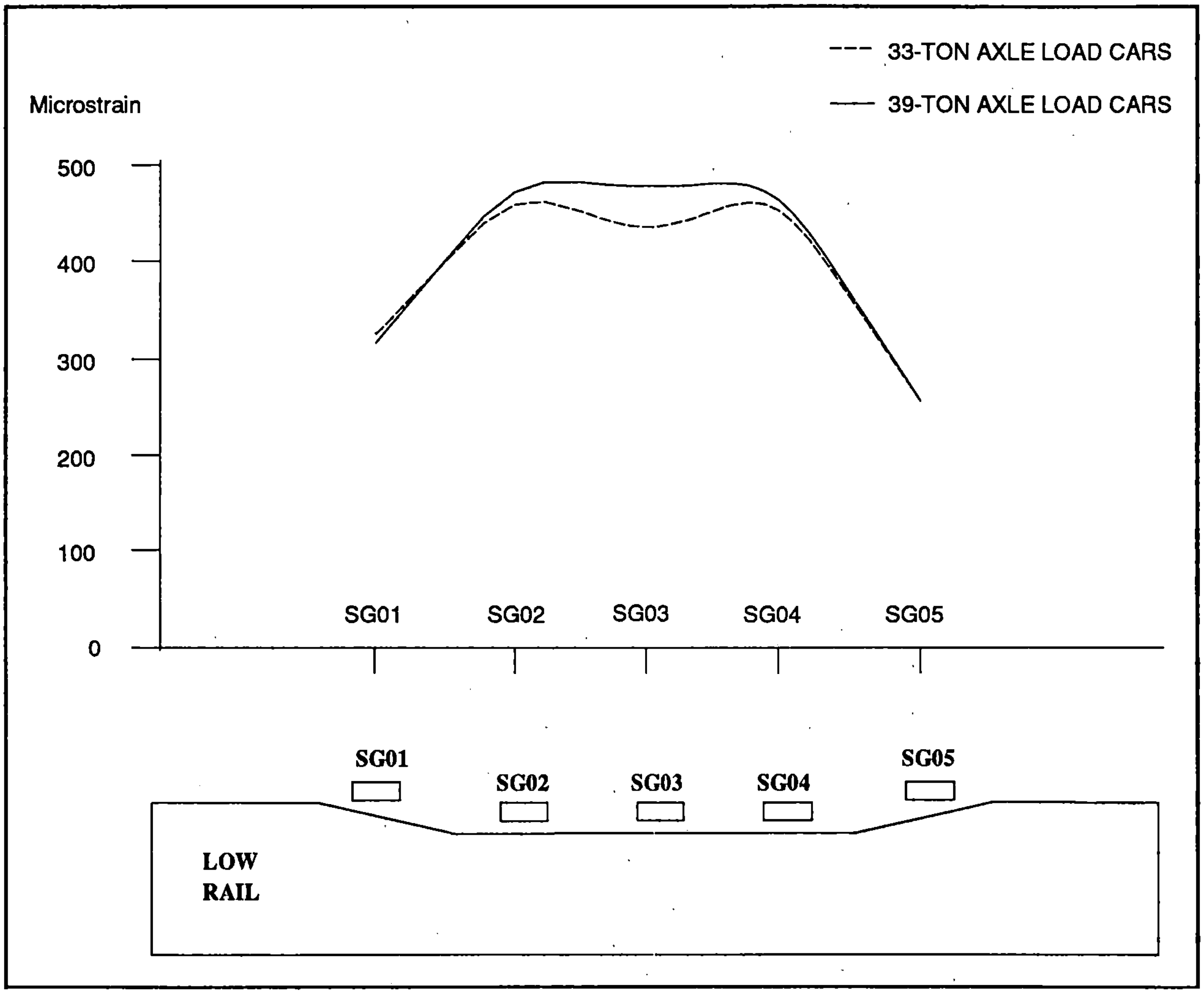

Figure 14. Comparison of 95th Percentile Strains

5.0 CONCRETE TIE PERFORMANCE

Flexural cracks usually develop at the top surface of concrete ties due to negative bending and at the bottom of the tie under the rail seats due to positive bending.[10] During the 33-ton program at FAST, which included concrete ties on curves of 5- and 3-degrees and tangent track, flexural cracks were documented at the tie centers of 7.4 percent of the total ties in test after accumulation of 425 MGT. No rail seat cracking was observed on any ties during the 33-ton program.[11]

Between 20 and 90 MGT of 39-ton axle load tonnage accumulation, 15 ties in Section 03, or 2.6 percent of the total number of ties in the zone, and one tie in Section 33, or 2 percent of the ties in that zone, developed flexural cracks. The cracks were located on the sloped section of the low rail side (outside rail of the loop in Section 33) of the tie about halfway between the rail seat and tie center. The cracks extended completely across the top surface of the tie and, in the most severe cases, extended down the vertical face about 1.5 inches. Similar cracks were not documented during the 33-ton axle load program.

Small surface cracks were also observed at the tie centers on two adjacent Koppers ties at about 70 MGT. These ties supported a bolted rail joint and the cracks were caused by negative bending from impact loads at the joint.

As indicated in Figure 15, most of the cracked ties in Section 03 were located in pairs, and in one case, three consecutive ties were cracked. All cracked ties were located in the west half of the Section 03 test zone and, with the exception of two RT-7SS ties, were the two lightest ties in the zone. The mechanism causing the cracks was not defined; however, cracked ties were observed at 20, 30, 55, 75, and 90 MGT which roughly correlated with track surfacing activity at 15 and 70 MGT. No new cracks were observed after 90 MGT.

None of the cracked ties were removed from service and the cracks had no adverse affect on the performance of the tie or track. Twenty ties from throughout the Section 03 test zone were removed at 160 MGT for inspection of the bottom of the tie at the rail seat area for cracks due to positive bending. As was the case during the 33-ton program, none of the ties currently in test exhibited visual cracks due to positive bending under the rail seat.

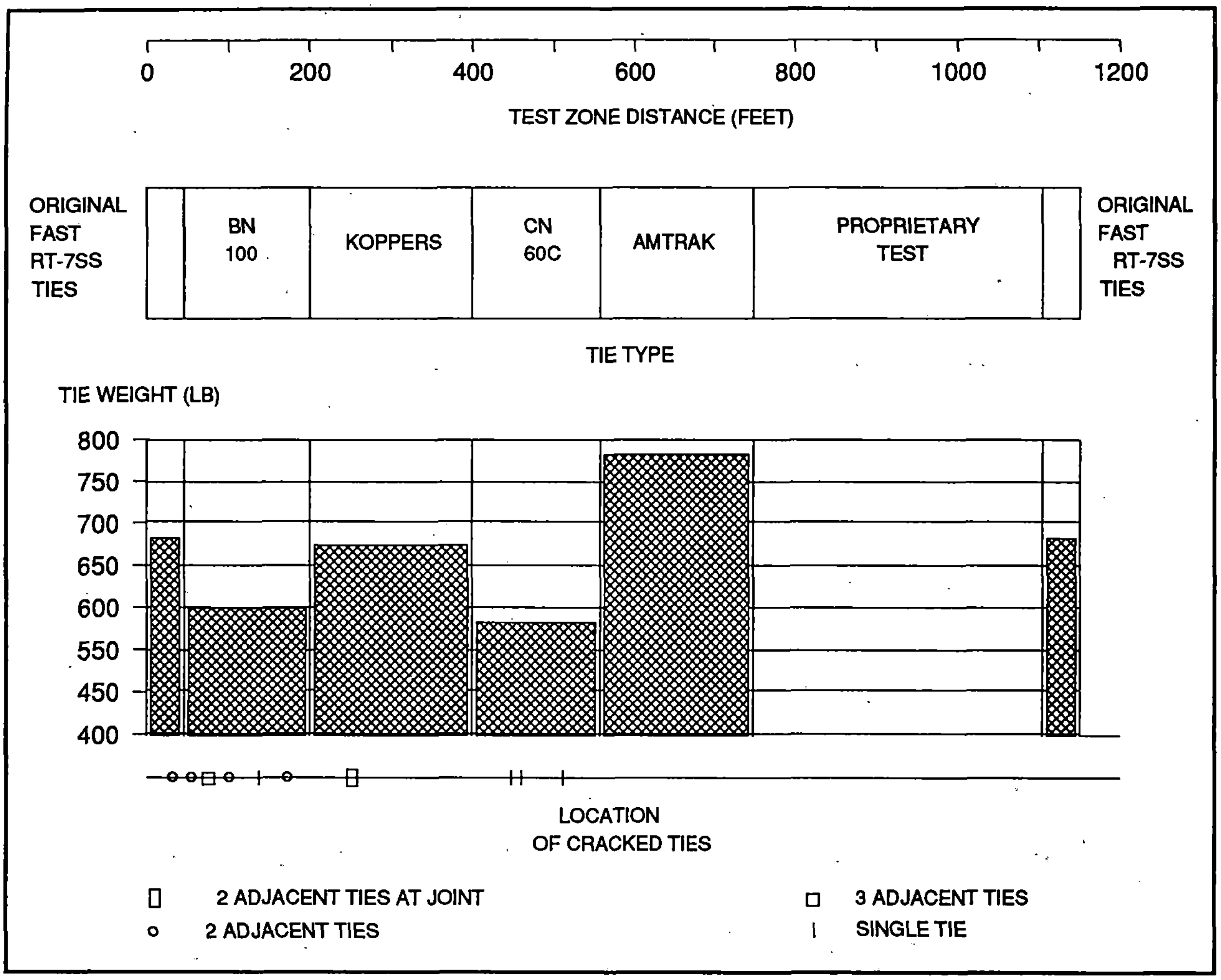

Figure 15. Location of Cracked Ties in Section 03 Test Zone

6.0 RAIL FASTENER PERFORMANCE

Long term fastener performance was quantified by documenting failure occurrences. Two types of failure modes were observed: fall-out due to loss of toe load and fracture. Fastener failures are summarized by tie type in Table 3. As implied in Table 3, rail fastener maintenance on concrete ties was not significant during the test. Data presented at the FAST Engineering Conference in November 1981 showed 16 percent of the 601A clips (the only fastener type common to both programs) fractured and 22 percent failed due to toe load loss during the first 400 MGT of the 33-ton axle load program.[11] It remains to be seen if long term fatigue will increase the number of failures.

Table 3. Summary of Rail Fastener Failures

FASTENER TYPE	FALL-OUT	FRACTURE	PERCENT	MGT
McKay	0	0	0	160
Pandrol 601A	16	1	5.3	160
Pandrol E (Koppers)	0	3	0.8	160
Pandrol E (AMTRAK)	0	2	0.2	160
Pandrol E (ITISA)	0	2	0.5	38
Pandrol E (CN 60D)	0	0	0	93

7.0 CONCLUSIONS

Conclusions of the Concrete Tie Experiment after accumulation of 160 MGT of HAL traffic are as follows:

1. There were no concrete tie failures during the test period. Fifteen ties, or 2.6 percent of the ties in the Section 03 zone, and one tie in the tangent zone, developed flexural cracks between the tie center and the sloping face on the low rail side of the tie during the first 90 MGT of the test. The depth of the cracks extended a maximum of 1.5 inches into the tie surface. Similar cracks were not observed during the 33-ton axle load program. Two ties exhibited tie center surface cracks at a rail joint location. There have been no new cracks noted since 90 MGT, and all cracked ties have remained in service.
2. Zero percent of the McKay, 5 percent of the Pandrol 601A, and less than 1 percent of the Pandrol E clips failed during the test period resulting in minimal fastener maintenance effort on concrete ties.

3. Dynamic axial strains measured across the tops of three consecutive BN 100 ties indicated the largest tensile strains occurred in the center third of the tie corresponding to negative bending. The tensile strains near each rail seat had about half the magnitude of the strains recorded in the center third of the ties. Increased strains due to axle loading was significant only at the tie center where a 13 percent increase was measured at the 90th and 95th percentile levels of the distributions.
4. The vertical rail forces in the concrete tie zones, as measured with wayside and instrumented wheel sets at 100 MGT, were typical of forces measured at other curves on the HTL. The wayside data from a single site in Section 03 showed a median vertical force of 35,000 pounds on the low rail and 43,000 pounds on the high rail. The median wayside lead axle lateral force of 7,000 pounds on the low rail and 12,000 pounds on the high rail were also typical of other 5-degree curve locations. Instrumented wheel set data showed lead axle lateral forces on the high rail exceeding 20,000 pounds in all Section 03 subsections, which is slightly higher than curving forces typically measured at FAST.

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APPENDIX A

FAST HISTORY, OPERATION AND MAINTENANCE OVERVIEW

by

Richard P. Reiff

INTRODUCTION

To the North American railroad industry, FAST, the Facility for Accelerated Service Testing, means track testing. Since its inception in 1976, well over 1 billion tons of traffic have been operated over a closed loop of track under carefully controlled and monitored conditions. Countless labor-hours have been expended in train operation, track maintenance, measurement, documentation efforts, and data analysis.

This appendix provides readers with an overall background to the FAST program. During the last 4 years, a controlled set of experiments has been conducted to determine the engineering impact to track and mechanical components when subjected to a controlled increase in applied axle loading. Data from these trials is being made available to the industry to provide component performance information as an aid in determining the most safe, reliable, and efficient method of operating a railroad system.

Particular emphasis has been on the effects that heavier axle loads have on track materials and maintenance procedures.

BRIEF HISTORY OF FAST

In September 1975, a report recommending a facility to study wear and fatigue of railroad track and equipment was issued by the Association of American Railroads (AAR) and the Federal Railroad Administration (FRA). The following spring track construction began at the High Speed Ground Test Center, Pueblo, Colorado, (now the Transportation Test Center). The first loop covered 4.78 miles (Figure 1) and utilized some of the existing Train Dynamics Track to reduce construction costs.

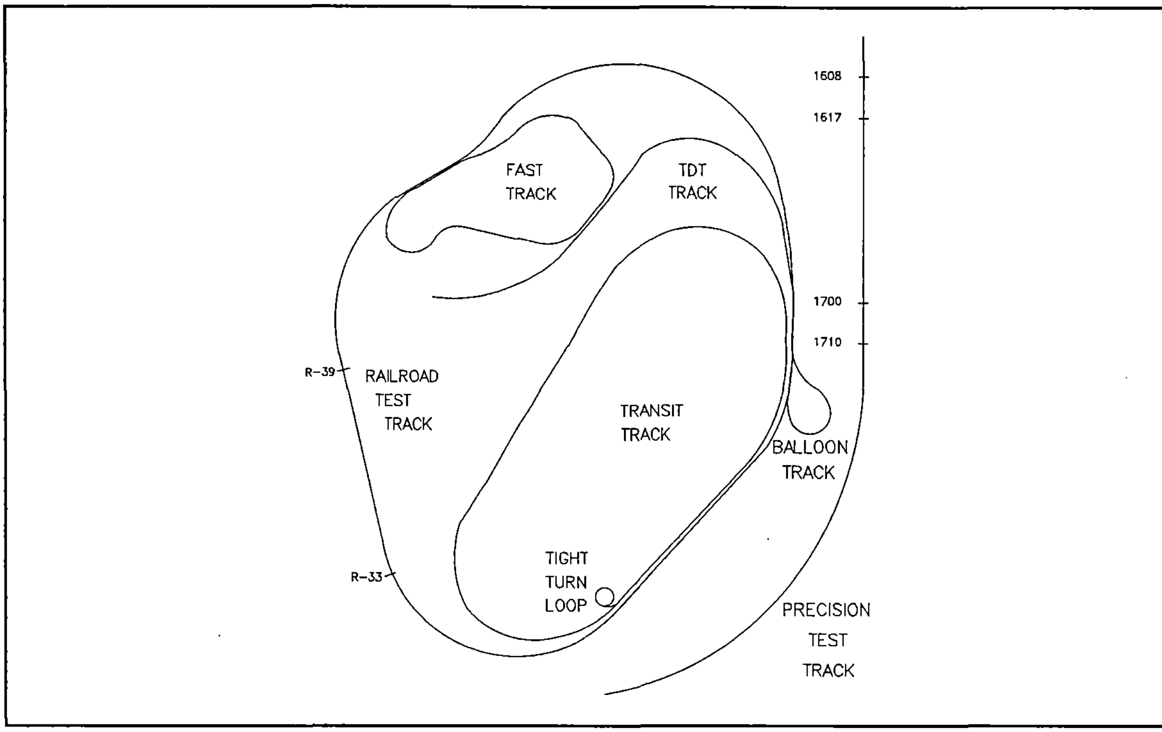


Figure 1. Test Tracks at High Speed Ground Test Center, Pueblo, CO, Showing General Location of FAST

On September 22, 1976, the first FAST train began accumulating tonnage on the dedicated test track. Since that time, a test train in various configurations and under a variety of test conditions has continued to operate.

The original FAST program was sponsored by the FRA, with all operating and measurement costs being the responsibility of the government. The railroad industry contributed significantly to the program by providing technical assistance and equipment, and by transporting materials for construction and maintenance.

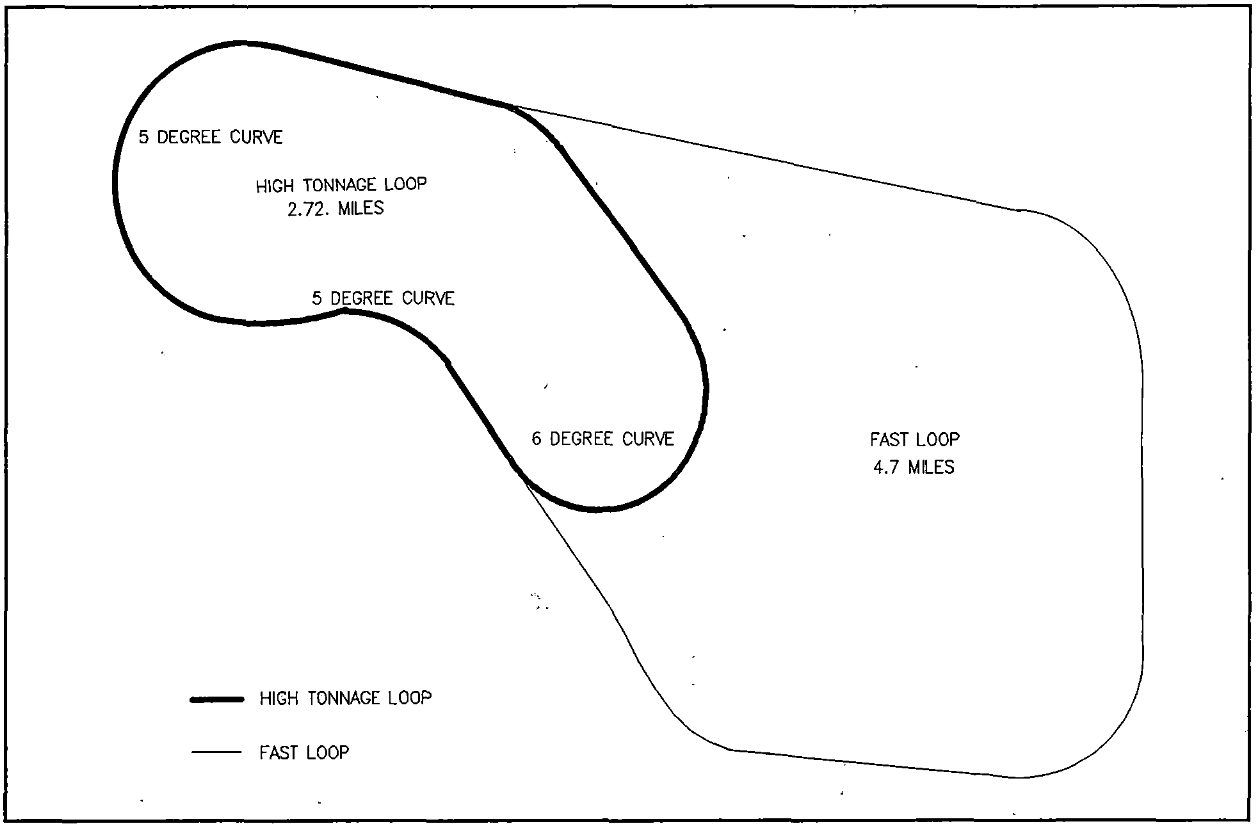


Figure 2. High Tonnage Loop

After 1977, government emphasis at the test center shifted away from high speed transportation to research of conventional transportation modes. The testing center was renamed Transportation Test Center (TTC), and in late 1982, government policy changed the operational procedures making the AAR solely responsible for its operation and maintenance.

FAST also continued to change. The annual FAST program operating budget had steadily decreased over a period of five years and, by 1985, it was apparent that the expense of operating a full train over the 4.78 mile loop was no longer affordable. To permit continued operation of FAST, a cut-off track was proposed, designed, and constructed using AAR funds (Figure 2). The cut-off track, approximately 1.3 miles, effectively reduced the loop from 4.78 miles to 2.7 miles. The new loop, named the High Tonnage Loop (HTL), consisted of one 6-degree curve and three 5-degree curves. All curves in the loop utilized spirals 300 feet long. As with the original loop, the HTL was divided into a number of test sections, which made inventory, maintenance, and measurement activities easier to document.

Completion of the HTL in June 1985, significantly reduced operating costs and allowed continuation of the FAST program using the original 33-ton axle load consist.

Since 1976, FAST has monitored tonnage applied to all test sections. This is accomplished by having every car and locomotive weighed and assigned a control number. This number is used to monitor daily train consist makeup and, when combined with the lap count for each shift, allows an accurate determination of applied tonnage over the loop. Each train operation is monitored in such a fashion, except for occasional work trains used for ballast dumping, rail unloading, or other track maintenance support functions.

Details of HTL Operations
33-ton Axle Load Phase

Along with the HTL came minor changes to the method of train operation. At the start of the HTL operation, a major rail fatigue test was initiated that required different operating characteristics than was used before. Train operation under the previous FAST policy controlled train direction so that both clockwise and counterclockwise operations were balanced. The train operated only counterclockwise on the HTL. The main reason was that lubrication, applied from a wayside lubricator, could be controlled from one location. (A calcium soap base lubricant with 11 percent graphite has been utilized at all wayside lubricators at FAST.) The combination of single directional operation and the use of wayside lubricators created the intended differential in the lubrication -- more near the lubricator, less at distances remote from the lubricator. By installing like or identical rail sections at various locations around the loop, the effect of a different lubrication levels could be assessed.

The shorter length of the HTL, 2.7 miles opposed to the original 4.78 miles, necessitated a major change in the signal system. The original signal system configuration was composed of a basic 3 block, direct current track circuit design. It utilized conventional, off-the-shelf signal components. Signal spacing on the HTL, however, prevented the proper function of this system as the block lengths would be so short, relative to the length of the train, that the locomotives would be continuously operating on a yellow approach. The signal system, which was solely used for broken rail protection and not block control of trains, was redesigned to function only as a broken rail detector.

As a result of the revised system, the outside and inside rail of the loop was fully insulated from each other, and each rail became its own independent signal loop. One master insulated joint was installed at a location on the outside and inside rail. Independent power supplies feed each circuit, with each loop of rail becoming its own continuity check circuit. Due to the short blocks, only a red (stop) or green (proceed) indication is now given. By using switch control boxes and additional insulated joints at turnouts, signals will also display red if a switch is thrown for an incorrect route. This revised signal system has been successful in detecting broken rails, joints, and improperly aligned turnouts.

Another variation initiated with the start of the HTL was to lubricate only the outside rail of the loop. Previous tests were conducted by alternating operating periods of lubricated rail (both rails) and dry rail. Typically 40 MGT of lubricated operation was followed by 10 to 15 MGT of dry rail, with this sequence repeated over a number of cycles. The new rail fatigue test required a long term (150 or more MGT) period of fully lubricated rail, without extended dry operation. Such a long lubricated test period would have prohibited the testing and evaluation of rail in the dry mode.

By only lubricating the outside rail, and leaving the inside rail dry, the one reverse curve (Section 7) on the HTL would have a dry gage face and offer a site for evaluating dry wear characteristics (Figure 3). As the train was turned end-for-end on a scheduled basis (but operated only in the counterclockwise direction), some contamination of the inside rail was observed immediately after train turning, but rapidly disappeared.

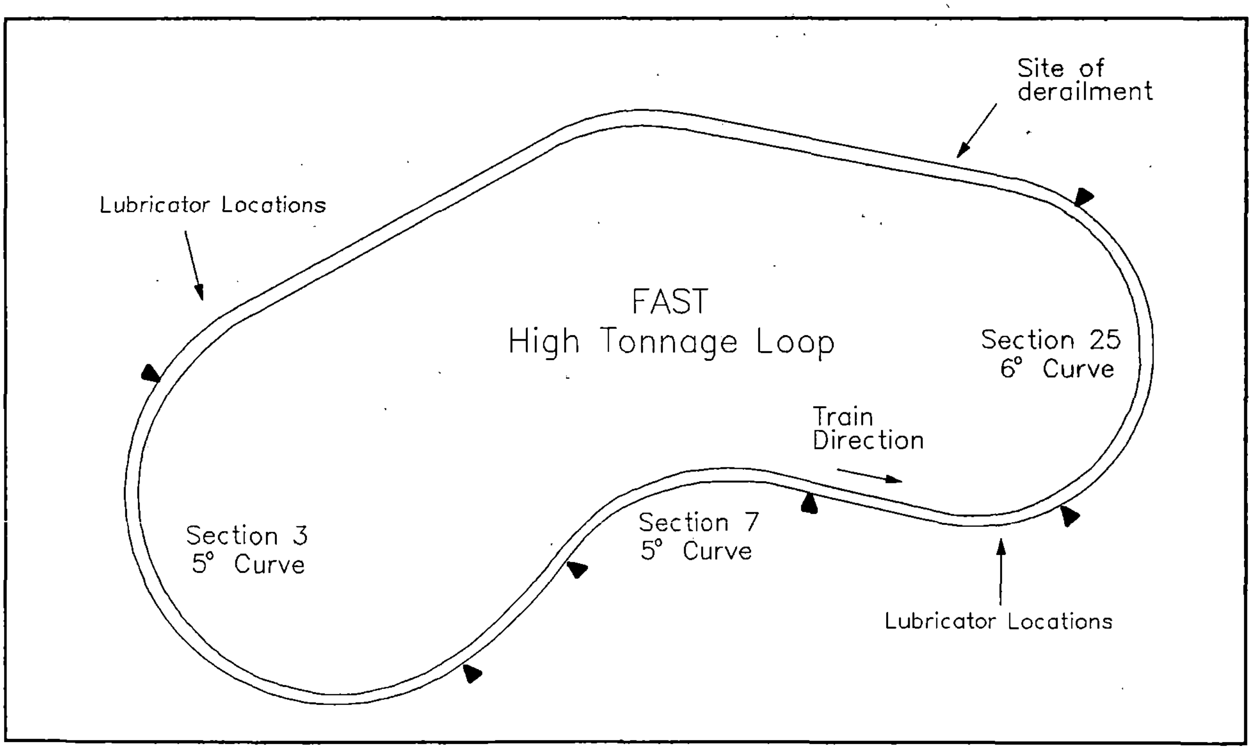


Figure 3. Lubricator Locations on the High Tonnage Loop

In July 1986, a major derailment occurred with the FAST train when the inside rail, after the exiting spiral in Section 25, overturned. Although track in this area was visibly in good condition, subsequent measurements located several pockets of weak gage restraint. A number of tests were conducted to determine the cause of the rail overturning. It was determined that under extreme differentials of high rail to low rail lubrication (high rail over lubricated, low rail extremely dry) a high truck turning moment could be obtained especially with locomotives in traction. It was suggested that this high moment accelerated the fatigue of wood tie fastener support near the derailment area, until rail rollover occurred. Results of this study are reported in AAR report R-712, "Effect of Track Lubrication on Gage Spreading Forces and Deflections," by K. J. Laine and N. G. Wilson, August 1989.

To eliminate, or at least reduce high differences of lubricant effectiveness between high and low rails without severely impacting the rail wear test, a very small amount of lubrication was required on top of both the high and low rails. Since the high (outside) rail of the loop was already lubricated, it was decided to place a small amount of contamination on top of the low (inside) rail of the loop. This was accomplished by installing some modified Fuji roller lubricators on cars kept near the end of the train. These lubricators were configured to lubricate the wheel tread (NOT THE FLANGE) with a very small amount of lubricant.

As an added safety check, gage widening "tell tales" were installed at a number of locations around the FAST/HTL loop (Figure 4). The tell tale is a small spring loaded device that provides an indication of maximum gage widening at that location due to the action from a passing train. The track inspectors at FAST routinely monitor these devices and check to see if excessive gage widening is occurring. This provides a safety check and gives advance notice if impending loss of gage holding ability is occurring.

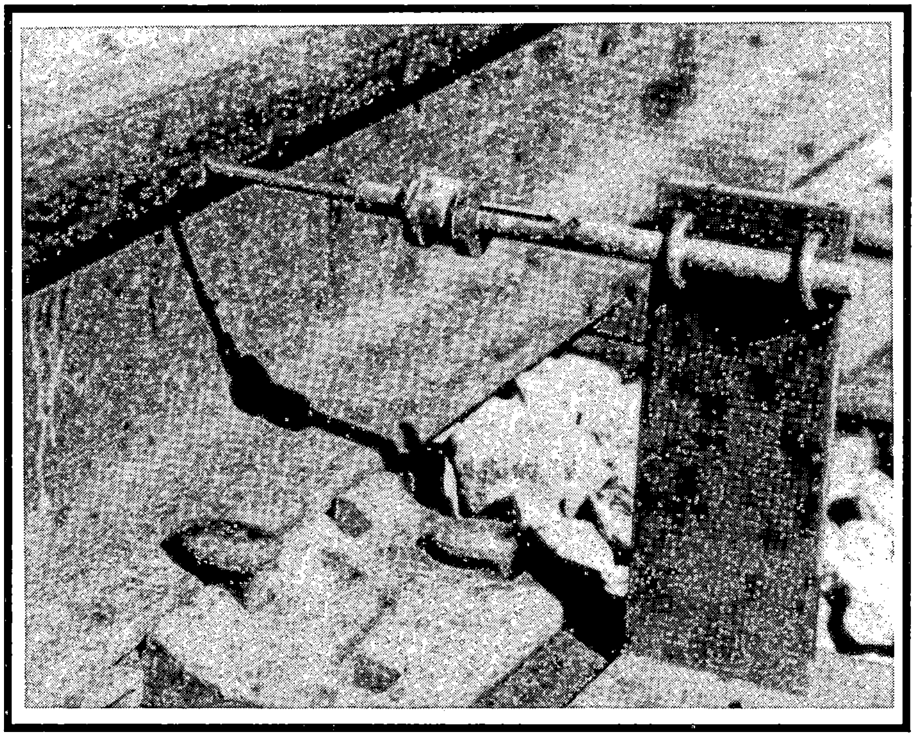


Figure 4. Tell Tale Installed on the HTL

Background and Need for the HAL Test Program

The completion of the 33-ton axle load (100-ton car) phase of the HTL occurred March 28, 1988. A total of 160 MGT was operated in the HTL configuration, while those parts of the HTL that utilized the original FAST loop had a total of 1023 MGT.

Up until this time the FAST consist was made up entirely of 100-ton-capacity cars, which resulted in a weight on rail of 263,000 pounds per car. Occasionally a few 89-foot flatcars, tank cars, and other less than 100-ton capacity cars were operated for special tests. The 100-ton car, as it is commonly referred to, has an axle load of 33 tons. The standard for such equipment includes 36-inch diameter wheels, 6 1/2 by 11-inch wheel bearings and a truck wheel base of 5 feet 6 inches (see Figure 5); this is the maximum weight on rail that is currently accepted for unrestricted interchange of equipment in North America.

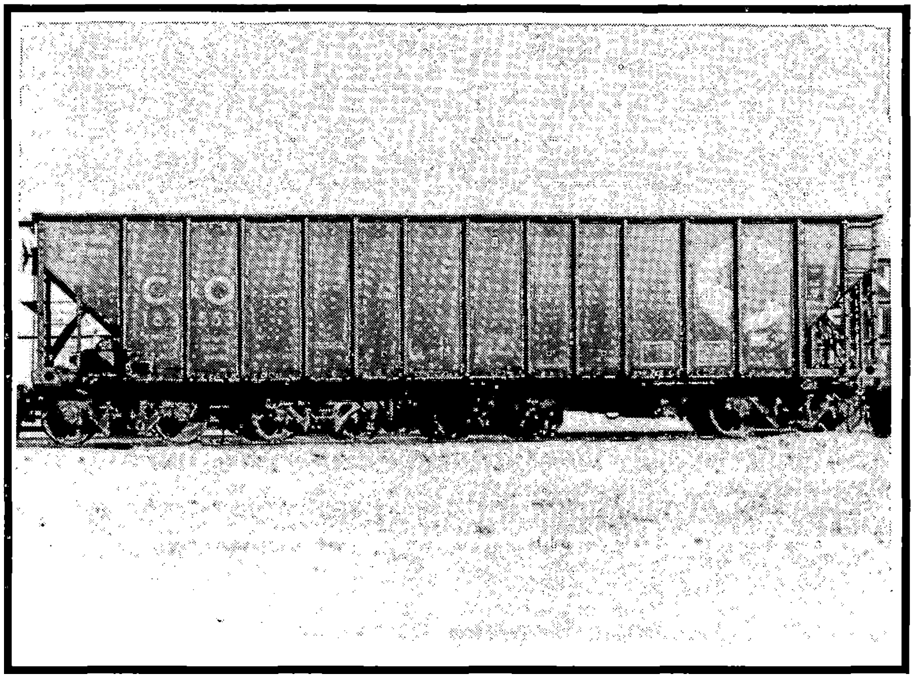


Figure 5. Typical 100-ton Capacity Car

The industry Vehicle Track Systems (VTS) group became involved with HAL testing in 1988. Under VTS direction experiment plans were revised to incorporate current industry concerns. The FAST Steering Committee recommended that the operation of the HTL continue, but that the train weight be increased to a 39-ton axle load. The purpose of the continuation would be to document the effect of heavier cars on existing track structures since some do exist and operate daily in North America. Examples include the Detroit Edison coal train, which consists of 125-ton-capacity equipment. These cars have larger wheels (38" diameter), larger bearings (7" X 12") and a longer truck wheel base (6'), as shown in Figure 6a and 6b. Table 1 summarizes the differences between 100- and 125-ton-capacity cars.

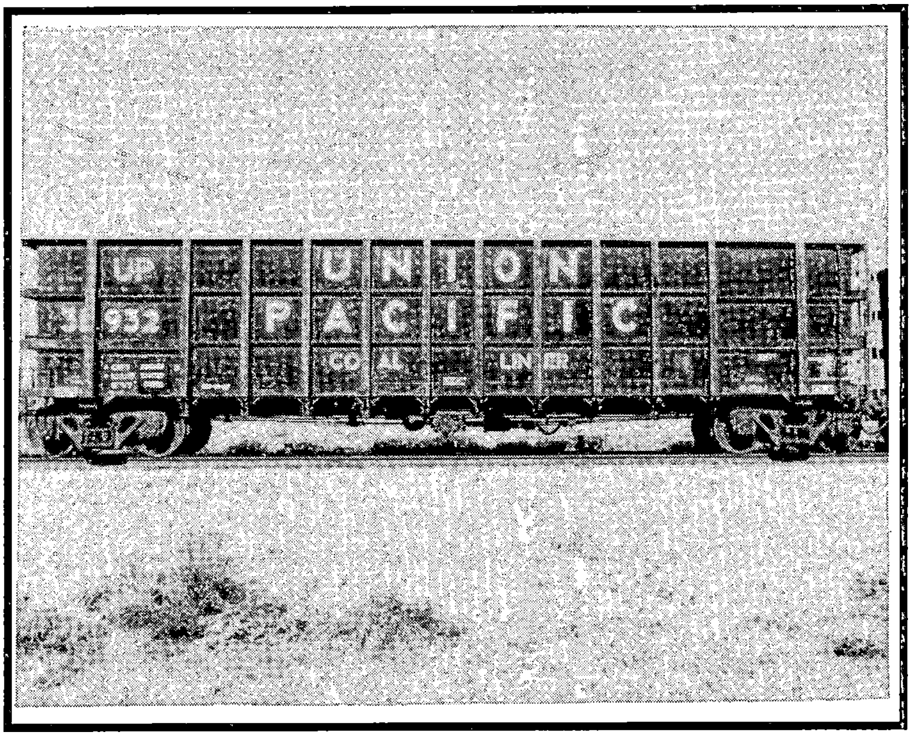


Figure 6a. Typical 125-ton Capacity Open Top Gondola

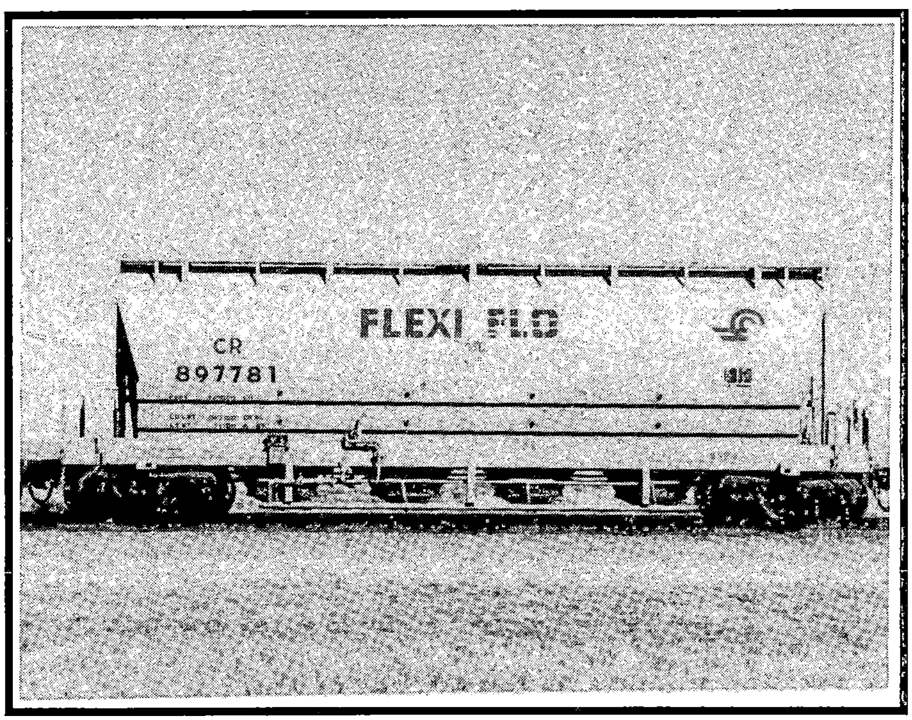


Figure 6b. Typical 125-ton Capacity Covered Hopper Car

Table 1. Differences between 100- and 125-ton Capacity Cars

COMMON NAME	ACTUAL CONFIGURATION
100-ton car	100 tons of lading 31.5 tons of empty car weight 131.5 tons on the rail 263,000 lbs on the rail 33,000 lbs per wheel (33 kips) 36" diameter wheel (33-ton axle load)
125-ton car	124.5 tons of lading 33 tons of empty car weight 157.5 tons on the rail 315,000 lbs on the rail 39,000 lbs per wheel (39 kips) 38" diameter wheel (39-ton axle load

Where heavier axle load cars are already in operation, they are not the sole traffic over a line. For this reason it is impossible to determine the exact damage factor that the heavier car load applies to the track. Maintenance prediction, for lines that may soon see a large amount of these heavier cars, is therefore difficult to determine. Thus, in order to obtain a better understanding about such degradation and wear rates, and fine tune track degradation and performance models, it was decided to operate the HTL using a heavier car.

The Heavy Axle Load (HAL) testing program was initiated in 1988. Up until this point in time, all FAST operations were funded solely by the FRA. For the first time in the history of the FAST program, funding for train operation use and data collection was supplied from both FRA and AAR funds. Guidelines for experimental goals were established as follows:

- Utilizing 125-ton equipment, repeat as near a possible the basic experiments conducted with 100-ton equipment during the final 160 MGT of the HTL.

- The only major variable was to be that of increasing the axle load; thus car type, train speed and configuration, and track layout would remain the same.
- Data would be collected to determine the effect, if any, on increasing the axle load.
- Data would also be collected to assist in validating existing track performance and deterioration models.

HAL TEST SCHEDULE AND PARAMETERS

HAL experiment plans were prepared after reviewing the results of the 160 MGT of 100-ton traffic on the HTL. Minor changes were made where results indicated a change in test procedures was needed, or where direct back-to-back comparisons could not be made. In some cases, where comparative data was simply not available, new test plans were drawn up.

Track rebuilding efforts began in April 1988, and a completed loop was made available for testing in early July. The track loop for the HAL Test was essentially the same as that for the 33-ton axle load (HTL) period, with the exception of adding a "by-pass track" (Figure 7). The loop was divided into test zones, which were identified by numbers.

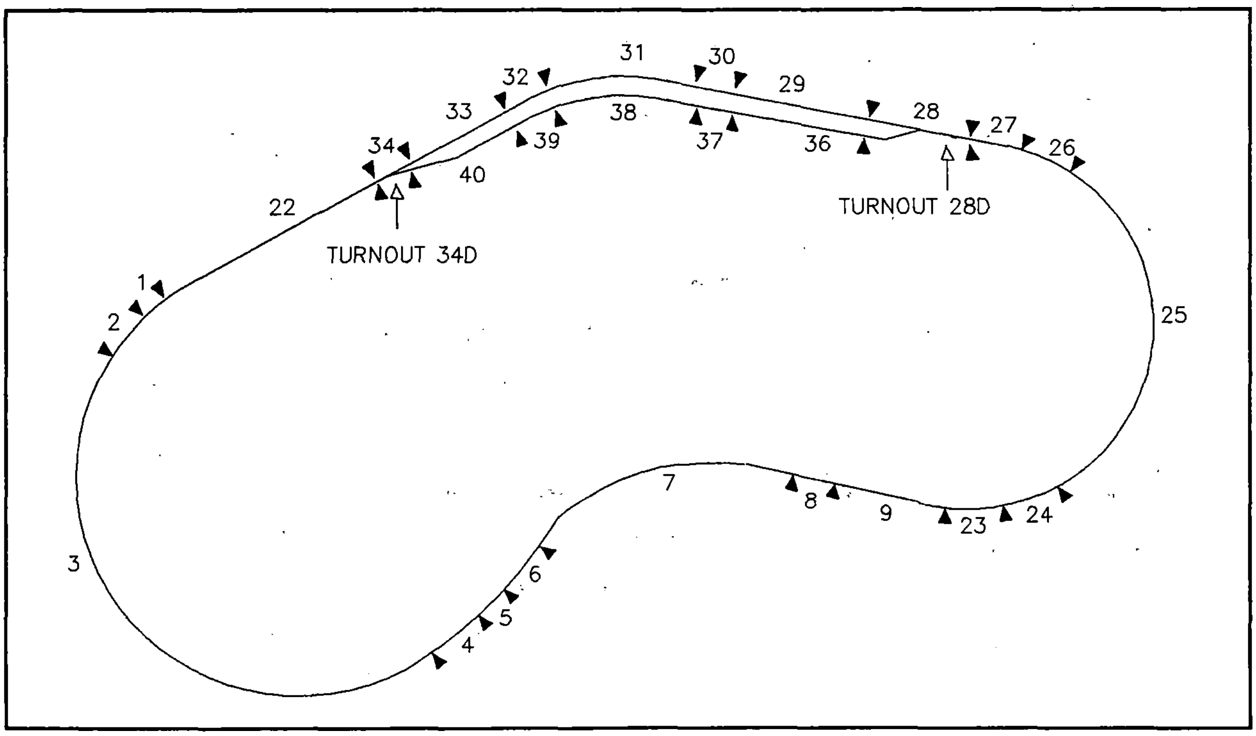


Figure 7. Map of HTL with By-Pass Track Added at Start of HAL Operations

The by-pass track, or siding, provided additional operating configurations and testing opportunities. The primary purpose of the by-pass was to permit operation over turnouts in both the straight-through and diverging route directions. FAST schedules called for 20 percent to 30 percent of the traffic to operate over the by-pass, thus applying tonnage to diverging route turnout components.

An added benefit to this type of operation was that it allowed track experiments that required small but controlled dosages of traffic between measurement and inspection cycles to be conducted. It was possible to operate as little as one train or as much as one full shift (0.01 to 1.35 MGT) during any given shift over the by-pass, thus affording selected track experiments controlled increments of tonnage between inspection periods.

After track rebuilding efforts were completed in August 1988, train operation began immediately. Small increments of MGT accumulation required by the Ballast Test, located on the main loop, resulted in low MGT accumulation rates during the first month. Rapid accumulation of tonnage began in October 1988, with the first 15 MGT of the HAL program operating in a dry, no lubrication mode.

The initial dry mode was operated for several reasons:

- To obtain early dry wear-rate data for "quick look" purposes
- To break-in rail and wheel profiles to a "worn" shape
- To provide a conformal worn rail/wheel profile on selected test rails for rail fatigue information

The 15 MGT dry mode was completed in January 1989. By design, a large amount of test rail was replaced to allow installation of "lubricated only" rail in support of fatigue testing. At the same time, a large amount of transition rail was replaced due to excessive wear observed during the dry operation.

Fully lubricated operation was initiated in March 1989, and continued until an additional 135 MGT was applied on April 20, 1990. During this period a number of interim measurements, minor rebuilds, and the replacement of a major turnout occurred. A total of 160 MGT of HAL (39-ton) traffic was applied to the loop.

HAL Track Description

A detailed description of the HAL loop, initial experiments and an overview of train operation are contained in Appendix B. Refer to this section for detailed descriptions of track sections, experiments, measurements and other items.

FAST/HAL TRAIN MAKEUP/OPERATION

The HAL train consists almost entirely of 39-ton axle load cars, as detailed above. Train length varied from 60 to over 75 HAL cars, with the addition of up to five standard 33-ton axle load (100-ton capacity) cars for mechanical test purposes. The 33-ton axle load cars were included for wheel wear control measurements and carried known defective bearings in support of mechanical tests.

Under normal conditions, four or five 4-axle locomotives (B-B truck configuration) were used to pull the consist; an example is shown in Figure 8.

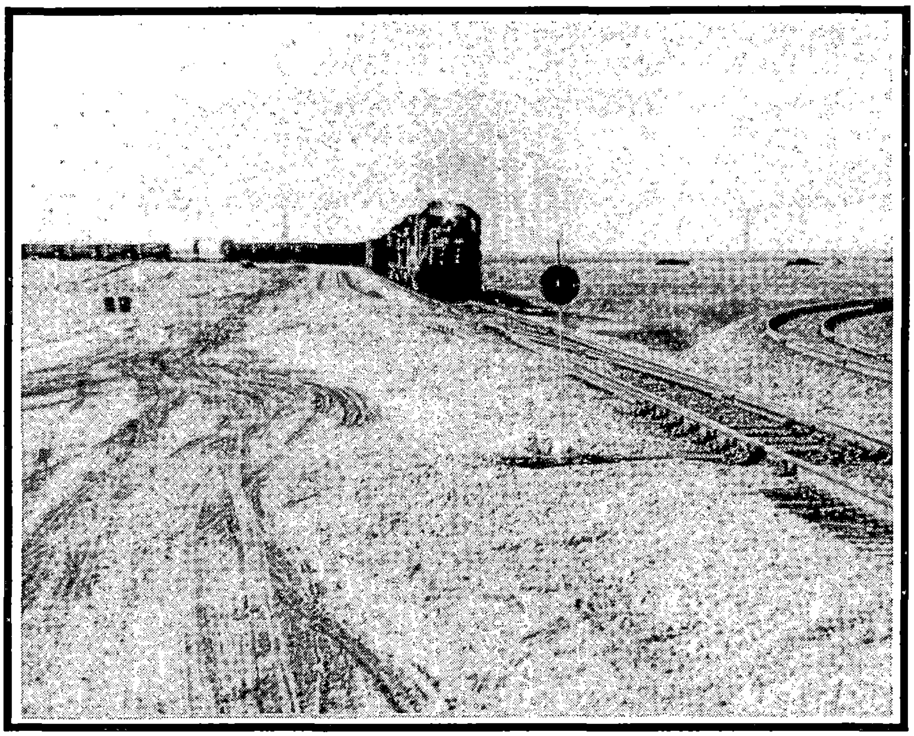


Figure 8. Typical HAL Train in Operation

These usually consisted of EMD GP38 and GP40, and GE U30B locomotives loaned to the FAST program by AAR members. On occasion, due to locomotive maintenance requirements, a rental or TTC locomotive was used to ensure adequate horsepower. Six axle (C-C) locomotives were used in the consist only during special test runs or as a work train. Train speed, after the initial "check-out lap" was held to 40 mph, with an average range of 38 mph to 42 mph. All curves were balanced so that at 40 mph a 2-inch underbalance condition occurred; that is, the high rail was loaded more than the low rail. The 5-degree curves were built with 4 inches of superelevation, while the 6-degree curve was built with 5 inches of superelevation. All elevation was run-out within the length of the 300-foot spirals.

Most train operation during the HAL testing occurred during early morning, third shift hours. Generally train operation was started at or near midnight and continued until 8 to 9 a.m., unless a broken rail or other defect required an earlier stop. The night operation was conducted for two major reasons:

1. Rail Temperature: Due to the short loop and 40 mph operation, the time between last car and locomotive passage for the next lap was about 2 1/4 minutes. The rail did not have sufficient time to cool, and daytime rail temperatures of over 160 degrees Fahrenheit had been recorded. This led to some track instabilities, buckles, and other problems. Night operation, without the added heat load of the sun, eliminated most track instability problems.

2. Track Time for Maintenance Crews: As will be discussed later in this document and in the track maintenance section, spot and "housekeeping" maintenance requirements soared during the HAL Test as compared to the conventional axle load period. The night operation allowed daily access to the track in support of maintenance functions.

During a typical eight hour shift, 100 to 120 laps could be accumulated; however, due to a significant problem with broken welds, many lap counts ranged between 65 to 90, and on occasion even less. This translates to about 0.6 to 1.35 MGT per eight hour shift, depending on train length. Train mileage, for a 65 to 120 lap shift, would range from 175 to 325 miles.

All cars were inspected every third shift of full operation, or within a 500 to 700 mile interval. Locomotive maintenance followed standard railroad daily, and 30- and 90-day inspection cycles.

Details of HAL Train Operation, Lubrication Application and Control:

As stated previously, train direction was primarily counterclockwise, with the following exception:

After every 3 MGT of operation (+/- 1 MGT), the wayside lubricators were turned off and the power run around the loop to the rear of the train. Then up to 30 laps (no more than 0.35 MGT) were operated in a reverse (clockwise) direction with no lubrication added to the track. The clockwise dry-down operation served two purposes:

1. It removed excess lubricant from top of the rail to aid in ultrasonic inspections

2. It provided beach marks (growth rings) which are used to monitor and track the initiation and growth of internal rail defects, especially shells and transverse defects

After completion of the ultrasonic rail inspection, generally every 3 MGT, the train was turned end-for-end, and reset for a counterclockwise operation. Upon restarting train operation, the wayside lubricators were reconnected and full lubrication was usually obtained within 15 to 20 laps. The main lubricator providing the basic lubrication was located in Section 24 (a spiral) just before the beginning of the 6-degree curve.

During periods of cold weather, a backup lubricator, located in Section 1 about halfway around the loop from the main lubricator, was used to establish and occasionally maintain required levels of lubrication (Figure 3).

Lubrication levels around the loop were recorded using TTC's Lubricant Level Gage (often dubbed the goop gage). This device (Figure 9) is used by the track inspector to monitor the visible level of lubricant on the gage face of the rail. Although this device will in no way determine lubrication effectiveness, since the same lubricant was used at all times during both the 33- and 39-ton axle load tests, the values recorded can be used to determine amounts of lubricant present.

The normal maximum lubricant level desired, as measured by the goop gage, is a +10. The rail at the beginning of the 6-degree curve, nearest the lubricator, had significantly more lubrication, averaging +20 to +30.

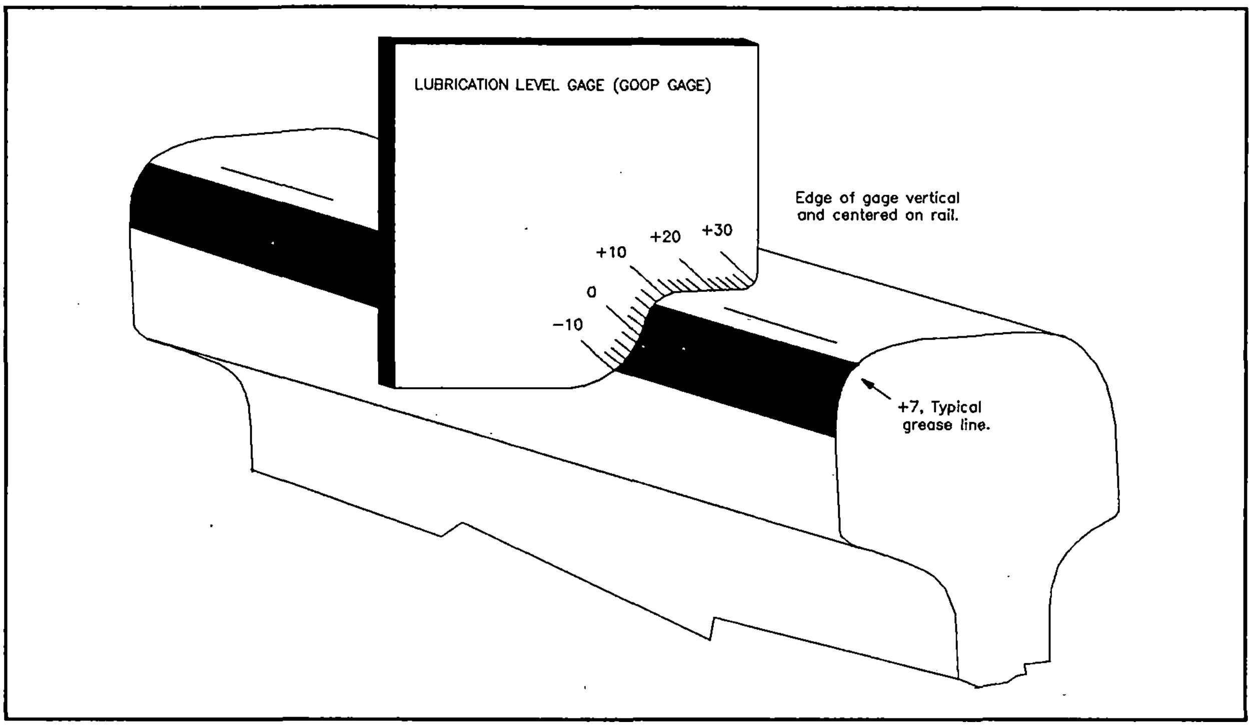


Figure 9. TTC's Lubricant Level Gage (Goop Gage)

Track Inspection Policy

The FAST/HTL loop is inspected continuously during operations and after every 2 MGT of operation during daytime periods.

During train operating periods for the HAL Test, which generally occurred at night, one track worker was utilized to inspect and adjust the lubricators. The duty of the second track worker was to constantly rove and look for any damage to the track, change in support conditions, broken components or loose bolts. By using road vehicles equipped with extra lights, this inspection was carried on continuously throughout the shift.

Additional information on track conditions was received from the onboard train crew. Due to the short nature of the loop, the crew soon learns the "feel" of the track and becomes aware of any changes. By use of radio contact, the ground inspector can readily be directed to a suspect area and ensure that an adequate track is being operated over.

The night crew had access to hand tools and some track machinery, which allowed them some repair capability. In some cases, such as a field weld failure, a two-worker crew was insufficient to pull rail gaps together, and operation of the train was suspended; however, most of the time minor repairs could be made and the train operation continued. Such repairs were made only in areas where experiment plans allowed, not where support data or measurements were needed.

The nighttime track inspectors monitored the entire loop, and, through inspection logs, documented areas that required immediate remedial repair, as well as areas of concern. Thus, items such as heavily corrugated rail, which might be causing undo ballast damage under train action, were noted for detailed daytime inspection.

The daytime track inspectors would make a detailed inspection, on foot, of the entire loop every 3 MGT, in conjunction with the ultrasonic inspection cycle. They would note all items requiring repair in the following categories: (1) fix immediately, and (2) schedule for repair.

Items such as missing fasteners, clips, and bolts would be in the "fix immediately" category. Other long-term planning items like tie replacement needs and grinding requirements would be in the "schedule for repair" category.

The track supervisor would advise the experiment monitor of repairs needed in test section areas, especially if such repairs might have damaged or altered measurement sites. When required, pre- and post-maintenance measurements were obtained in order to quantify the effect of the activity.

Track was generally allowed to degrade until it neared the FRA Class 4 limits. Such standards were monitored by the EM80 track geometry car (Figure 10) along with the above outlined visual/manual track inspection. In some locations, where no test was designated, the track inspectors and foremen were free to maintain track before Class 4 limits were met, depending on other work loads.

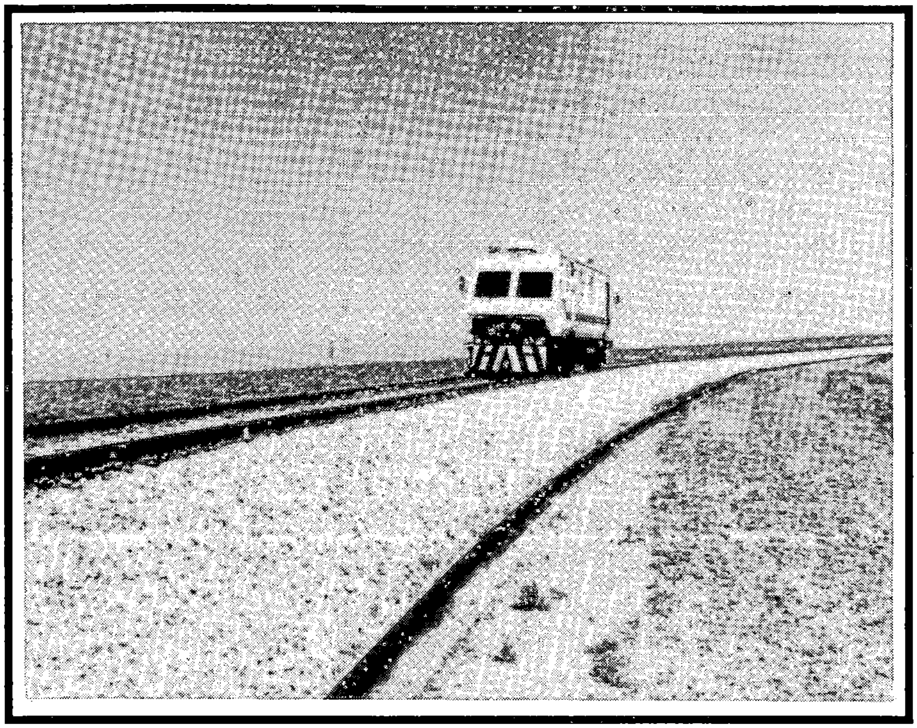


Figure 10. EM80 Track Geometry Car

Track geometry car inspections are scheduled after ever 5 MGT of operation to allow general monitoring of changes to gage, surface, line, and cross level. Extra inspections with the EM80 car are scheduled before and after specific maintenance functions, such as surfacing and lining, when such activities are over specific test zones.

An important item to note is that the track was not allowed to degrade below a level designated safe. Proper maintenance was always completed so that the track could sustain at least 1.3 MGT of additional traffic. Because of this, FAST may be defined as being "over maintained," a policy enacted and followed since 1976. On a revenue railroad, a turnout frog, for example, may be recorded as requiring grinding. Typically a 40 to 50 MGT per year line may operate 10 to 20 train moves during a 24-hour period between maintenance windows. Deferring maintenance in this example by one, two, or even three days generally will not cause an unsafe condition or undo damage to the item.

However at FAST, unless special conditions exist, one must plan for "worst case and best efficiency" train operations. Thus up to 135 laps (or train passes) of a fully loaded train, 12,500-ton, could be operated before the next maintenance window. With this in mind, with the frog grinding example described above, repairs would have been initiated for metal removal in advance to ensure that damage to the frog from excessive lip formation did not occur.

For this reason, all track degradation limits must be sufficiently high to allow for the anticipated extra degradation that a 1.3 MGT loading would apply at a given location. To permit this safety factor, certain items were prematurely maintained to ensure that a safe track structure would be available for an entire operating shift. Any comparison with other periods at FAST can be made with similar track maintenance limits in mind. The only change during the HAL Test was that, in some cases, the HAL train caused higher degradation rates at joints and other anomalies. This higher rate required extra caution when determining how far defects should be allowed to degrade before applying corrective maintenance efforts.

Interim Rebuilding/New Tests

During the course of the 160 MGT HAL operation, a number of minor changes to the original test configuration were made. As test components wore out or sufficient data was obtained on original items, new materials were placed in track.

A guideline for placement of most track components in the original HAL Test was that the item was already to be in general use by the railroad industry. As stated in the original HAL goals, the purpose for the initial HAL Test was to determine the effect of the HAL train on track and train components. While new and experimental components were not always restricted, the budget for HAL dictated that the first priority was to evaluate the effect of heavier axle loads on conventional track materials and structures.

Major test components that were added to the original configuration included:

- Replacement of the original AREA standard design #20 turnout with a state of the art heavy duty turnout with the same overall AREA geometry
- Addition of post tensioned concrete ties
- Addition of concrete ties designed for tangent track
- Addition of Azobe hardwood ties
- Installation of a Frog Casting Quality Test zone

The follow-on test program, in the form of at least a 100 MGT extension, will place more emphasis on new and improved materials that are designed to better withstand the effects of the HAL train environment.

General Observations after 160 MGT of Traffic

Experiments were conducted under the same conditions and constraints. These include the following major considerations:

1. All traffic was made up of loaded cars and locomotives. No empty or light cars were operated for any extended period of time.

2. All trains were operated at 40 mph except for the first and last daily train pass, and when a slow order (10 to 15 laps at 25 mph) pass was needed for testing purposes. All curves were elevated for the same 2-inch superelevation cant deficiency condition.

3. Ninety percent of the traffic was in one direction (counterclockwise); 10 percent went clockwise. This was accomplished in 300 lap/30 lap increments.

4. All operation was conducted with the outside rail fully lubricated and the inside rail slightly contaminated at all times. Every 3 MGT, dry-downs were conducted; however, some trace of gage face lubrication remained at all times, even after the dry-down.

5. Under normal operating conditions, train brakes were not used. Occasionally, when the signal system detected a broken rail, a standard 10 psi to 15 psi brake pipe reduction was made to stop operation. Other than that, air brakes were rarely used to control train speed.

6. Most equipment contained conventional design mechanical components, with three-piece trucks.

7. The TTC is located in the high plains of Colorado where natural moisture is relatively low -- approximately 11.5 inches per year. Subgrade support conditions are almost ideal for track construction; firm, sandy, and

well-drained soil. The winter season generally sees little in the nature of freeze/thaw cycles. Winter snows usually evaporate in one to three days, with relatively little moisture seeping into the ground.

Comparisons between 160 MGT of 33-ton and 39-ton experiments were made with the same gross tonnage applied. For comparison purposes, all track related data is tied into this net applied load. As the axle loads were different for the two periods, a different number of cyclic loadings occurred to obtain the same applied tonnage. The 39-ton axle load period had approximately 16 percent fewer loading cycles for the same 160 MGT period as the 33-ton axle load test configuration (Table 2).

Table 2. Differences in Cyclic Loading for 33- and 39-ton Axle Load Periods with the Same Net 160 MGT on the Track

33-TON AXLE LOAD TEST	39-TON AXLE LOAD TEST
15,850 Trains	13,370 Trains
4,820,000 Rail Loading Cycles	4,065,000 Rail Loading Cycles
114 Million Tons of Lading Hauled	120 Million Tons of Lading Hauled

Note: Track loading for equivalent 160 MGT application of track load using 4 locomotives, 72 car average train. Heavier car required approximately 16% fewer trains to apply same loading onto the track, and hauled approximately 5% more net tonnage.

Major Items Showing Significant Impact during the HAL Period

Quality control of maintenance activities became even more important at FAST during the HAL period. The higher axle load caused even minor deviations and anomalies to degrade at a rate faster than before, thus workmanship during repair cycles was critical.

Track maintenance items could not be deferred to the extent permissible under the lighter load. Even small anomalies would often grow rapidly, when left to be repaired by the next shift.

All track work required careful blending and transition into adjacent areas. Sudden transitions must be avoided to prevent introducing bounce modes in vehicles, which could initiate additional degradation at other locations. Uniform support conditions, with little or no change in resulting track geometry, afforded the lowest track maintenance effort.

The surface condition of the rail became even more critical. Joint batter, welds and mechanical joints, (Figure 11), and rail corrugations (Figure 12) occurred more often and grew more rapidly under the HAL program. Metal flow at rail ends and frogs required significantly more maintenance effort than before.

Field weld failures (Figure 13) played an important part in the efficiency of operation during the HAL Test. Frequent failures, which were not observed during the 33-ton phase, resulted in a significant impact to train operations. The need for improved quality control during the welding process as well as improved welding techniques and materials to withstand the heavier axle loads was noted. The standard mix content of most field welds often lead to excessive batter, especially when used on 300 Brinell hardness (Bhn) and heat treated rails of standard chemistry.

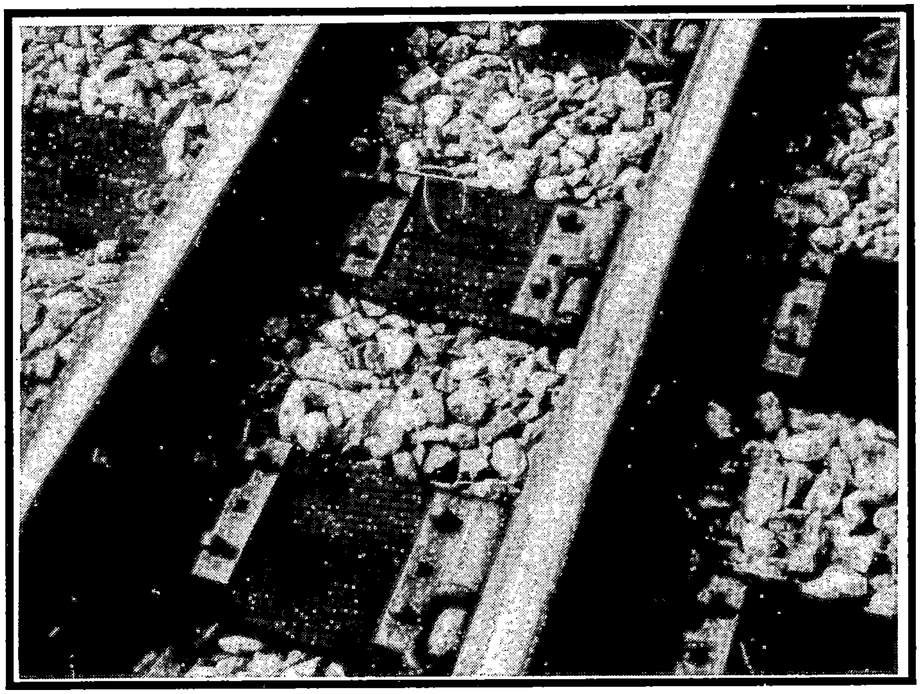


Figure 11. Typical Welded Rail Joint Batter

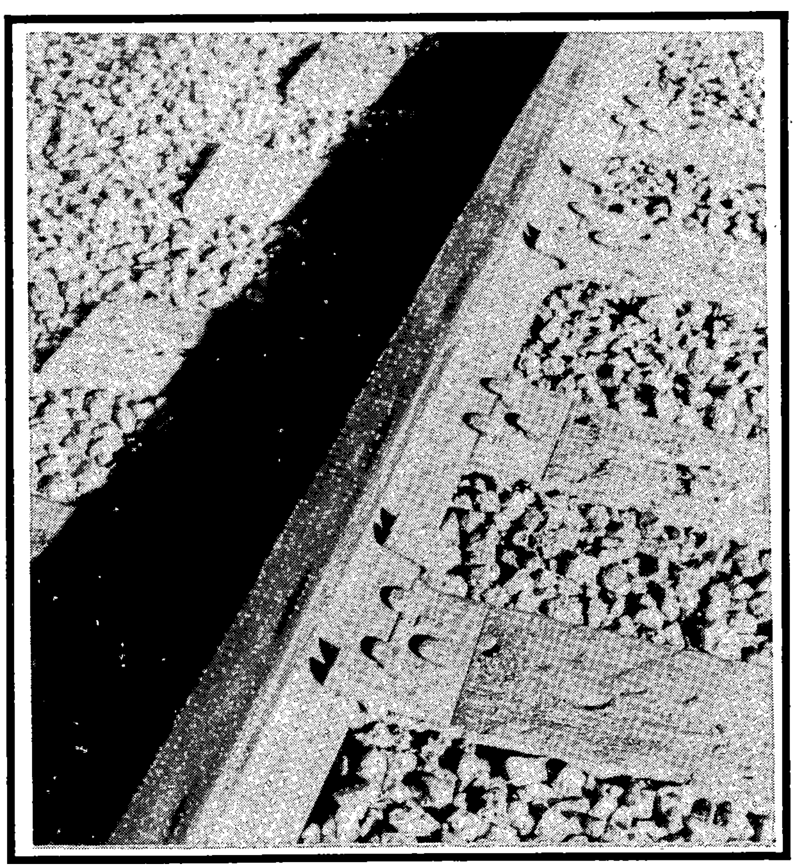


Figure 12. Typical Corrugations

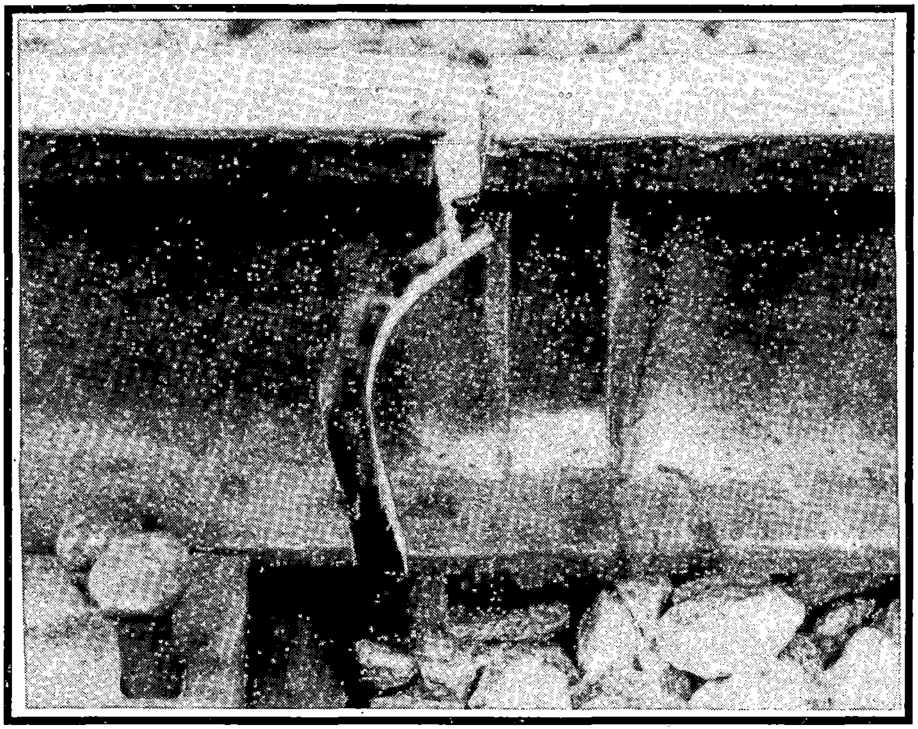


Figure 13. Typical Broken Field Weld

Under the HAL train operation, turnouts were second to field weld failures in the area of increased track maintenance. As with conventional field weld material, standard rail and frog components exhibited the shortest life and highest amount of maintenance and repair (Figure 14). Overall, turnouts required a significant increase in spot maintenance, grinding, and buildup requirements.

Figure 14. Typical Worn Frog Components

The overall track maintenance effort increased, with the following areas showing the highest demand.

1. Out of face grinding for corrugation control

2. Increased welding requirements

3. Immediate attention required for spot surfacing needs

4. Increased failure rate of field welds

In general, corrugations on tangent track, especially where standard rail was in place, became very common during the HAL Test. The increase in dynamic loads, due to vibrations, often required additional spot maintenance in these areas.

The heavier car emphasized problems using the lighter axle load geometry car. Low spots and pumping track areas, observed under traffic by the track inspectors, would not always show up as full depth defects on track geometry car inspection reports. The use of heavier geometry cars or heavier axle loads on geometry measuring equipment may eliminate this anomaly.

Many areas of the HTL were not totally rebuilt before starting the HAL train operation. In such areas, for example, where wood ties remained in place from the previous test period, more rapid tie degradation and higher replacement requirements than during a similar period with the lighter axle load were noted. Track inspectors had a more difficult time determining remaining tie life during the HAL train period, as the wood tie's ability to hold gage appeared to decline more rapidly, and with less visual indication. Hidden defects in the ties tended to degrade more rapidly, and with less visual warning, necessitating the replacement of more ties during cyclic renewals to ensure a safe operation.

The above observations are based on areas where back-to-back comparisons between 33- and 39-ton axle load data is available. A number of other test results from the 39-ton axle load phase include: localized cracking of selected concrete ties, early replacement of a standard turnout, and failure of one wood tie fastening system. Results from these tests cannot be compared to equivalent results under 33-ton axle loads at FAST simply because they were not under controlled tests during the HTL comparison phase.

These and other results were presented at the Workshop on Heavy Axle Loads, Pueblo, Colorado, October 16-17, 1990.

OVERALL TRACK MAINTENANCE IMPACT

Under the conditions of the FAST loop, the percentage of daily "spot" or "housekeeping" track maintenance effort increased significantly when compared to the axle load increase. Labor hours increased over 60 percent compared to an axle load increase of 20 percent.

The increase in spot maintenance requirements was determined by collecting records of all daily track maintenance activities recorded by field personnel. Each "routine" maintenance requirement, that is, an activity not associated with special requests due to experiment objectives, was assigned a standard labor hour rate. For example, each time a low joint required tamping a standard rate of 0.5 labor hours was applied while to repair a broken weld a standard rate of 16 labor hours per occurrence was applied. Also excluded were major component changeout efforts, such as major rail replacements due to wear, new test component installations, and other "capital improvement" work.

By eliminating the special request maintenance items, such as replacement of a weld due to laboratory analysis requirements, only those maintenance activities directly associated with track degradation were monitored. The use of standard labor hour rates for each activity also eliminated many of the inherent "unique" situations found at FAST. At FAST many maintenance activities require special care due to adjacent instrumentation, the need for pre- and post-measurements, and position of special test materials. Use of the standard labor hour rates permits the total maintenance demand to be normalized for comparison purposes.

The test loop was subjected to a number of changes during the course of the 33- and 39-ton axle load experiments. Both experiments, however, started out with track in approximately the same condition and with similar materials. As tonnage was applied, track materials were changed and new test materials installed, thus making direct comparisons more difficult as the programs progressed. Due to these changes comparisons after the initial 85 MGT are unreliable.

Figure 15 indicates the cumulative labor hours of effort for the following basic track maintenance categories: joint maintenance, rail maintenance, surface and lining operations, turnout maintenance, and miscellaneous. A total effort in labor hours is also shown. These values represent the total number of standardized labor hours for each maintenance category required to keep the track in the same general condition for the initial 85 MGT of each test train period.

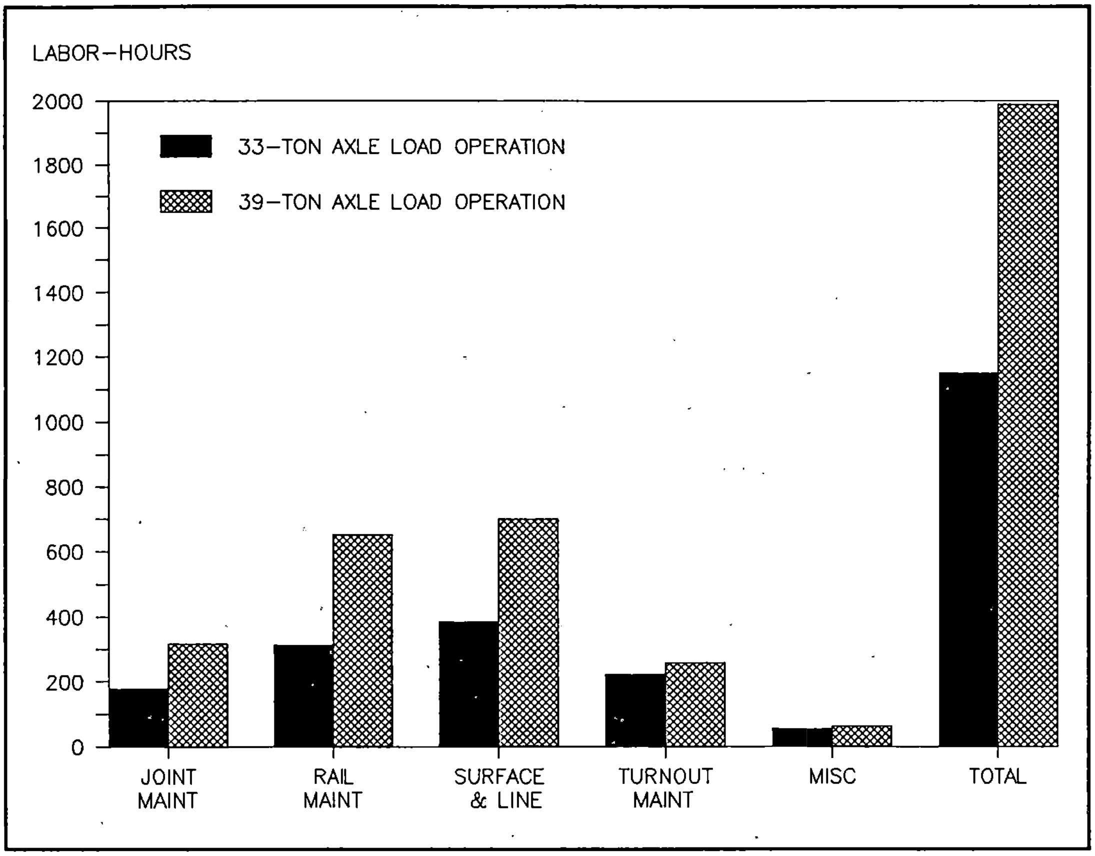


Figure 15. Breakdown of Track Maintenance Effort

Figure 16 shows the cumulative labor hour maintenance data by MGT for each test train period. For reference, the total labor hours for the 3-ton axle load test are shown beyond the 85 MGT base comparison period. Data beyond the initial 85 MGT baseline is shown for the 39-ton axle load test period. Labor hour maintenance totals continued at about the same rate per MGT as tonnage was accumulated to 100 MGT.

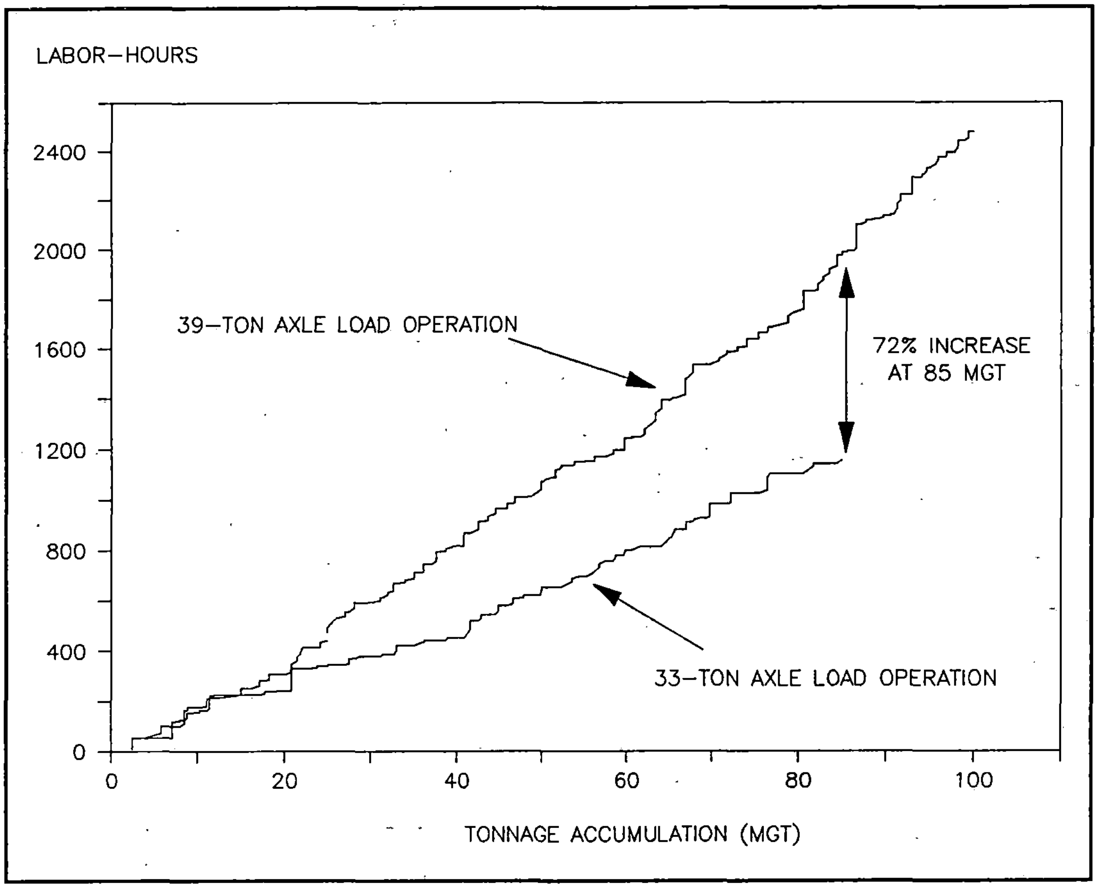


Figure 16. Track Maintenance Effort as a Function of Tonnage

The difference in cumulative labor hours after 85 MGT between 33- and 39-ton axle load test periods indicates a 72 percent increase due to the heavier axle load. Caution must be used in interpreting this data, as a significant error band in the total figures does exist. These labor hours represent spot maintenance demand, and as such is often dependent on the discretion of the field track supervisor. The data does not represent long-term replacement demand, such as out of face tie renewal, ballast work, or other capital investment related activities. The spot maintenance efforts represent comparison of activities needed to keep similar track at the same general geometry level during two periods of axle loads.

The long-term effects of rail wear, ballast work, wood and concrete tie life, fastener life and other capital intensive efforts have not been fully developed, but as the information and data trends indicate, the effect is not nearly as dramatic as the 72-percent increase in spot maintenance demand.

Results at FAST indicate that conventional track structure, as utilized by the majority of North American railroads, can survive 39-ton axle loads with some basic strategies which include:

- An increase in the attention to track maintenance detail and quality of work is required.
- Improved uniformity of work in blending repairs into the adjacent existing track structure will reduce non-uniform and impact loads.
- Areas of high impact forces, such as at frogs and within turnouts, require premium materials to withstand repeated loads
- Where premium materials are not used, such as in existing track that is to be subjected to a high percentage of increased axle loads, faster capital replacement will occur

Areas of Track Requiring Improvement

A number of basic areas of improvement have been identified for future evaluations. These are areas that could withstand the increased axle loads but required a disproportionately higher level of maintenance, based on FAST experience.

In areas where continuously welded rail (CWR) is utilized, which is the case in the majority of heavy mainline in North America, two major areas of improvement were identified:

1. The performance of field and shop welds declined significantly under the HAL train. In all cases weld batter must be reduced to lower the degradation of ballast and ultimately surface and lining demands. In the case of thermite type field welds the failure rate as well as batter rate was observed to be unacceptably high.
2. Where field welds are not practical or possible, such as at insulated joints or emergency plug repair sites, joint maintenance becomes critical. Emergency bolted plugs require immediate replacement with field welds when possible.

In areas where jointed rail is in place, early replacement with CWR is very desirable. Where complete replacement of jointed rail is not possible, or where programmed upgrades to an existing secondary line require operation over jointed track for a period of time, the FAST experience suggests the following:

- Eliminate jointed rail on curves. The few areas on FAST where jointed rail existed on curves resulted in significant track geometry degradation and high maintenance.
- In areas where jointed rail exists, repair of bent rail ends and loose fitting or worn bars must be completed immediately. Ballast memory was a higher problem under the HAL train than in previous FAST operations.
- Repeated tamping of joints, especially with certain ballasts that tended to become rounded with degradation, is ineffective. Repair of the rail surface problem (bent rail ends or joint bars) was required before a joint maintenance problem could be reduced.

Rail quality has improved over the last decade to where standard rail of 300 Bhn is usual for most installations, and premium rail of 340 Bhn and higher is found on most curves. Comparisons using 248 Bhn rail as a base are not directly applicable as many railroads have already eliminated this older rail on curves. There are cases, however, where older rail is still present on tangents of main lines and careful inspection may be needed before operating a significant amount of HAL type traffic. In the category of running surface materials, the following areas of improvement are suggested:

- Field inspections suggest that rail that corrugates easily should be eliminated or it will require increased out-of-face grinding maintenance. Corrugations on tangent track became common on the FAST loop in areas where older rail (less than 300 Bhn) was utilized. Even where 300 Bhn rail was used in tangents, corrugations were noted; especially, in turnouts. The requirement for premium rail in tangents needs to be investigated as a potential means of reducing grinding requirements.

- In turnouts, top quality materials are desirable. On FAST, the use of non-premium materials will lead to early failure along with high maintenance and repair costs. Rapid degradation was noticed where non-heat treated rails were used in components such as frog wing rails.
- Improved turnout geometry and component strength should be investigated to reduce spot maintenance requirements.
- Once started, the surface degradation leads to a rapid degradation of other components or adjacent areas, requiring spot maintenance activities to be scheduled on a frequent basis.

The items summarized above deal mainly with the ability of materials and components to withstand the heavier load.

General Maintenance Policies of Railroads in the Daily and Cyclic Inspection, and the Maintenance Duties of Track Personnel

Results of the FAST/HAL investigation point to the following areas where improvements to these duties would be beneficial where a large number of HAL type traffic is to be operated:

- Lower tolerance for deferred maintenance was noted. Small anomalies tend to degrade much faster under the HAL environment, thus reducing the allowable time between locating and repairing such defects.
- Improved methods of locating these minor defects will probably be needed, especially with automated track geometry systems. The need to identify small surface related defects, such as engine burns, low joints and other housekeeping requirements is increased.
- For long-term maintenance planning, wood tie integrity measurements are needed.
- Finally, once the above items are located, better tools for spot maintenance repairs may be needed. Spot work such as welding, grinding, and tamping of rail surface will take on even more importance with HAL traffic.

The major thrust of the HAL program to date has been to document the effect on track component wear and track maintenance requirements with increased axle load. Track, of course, does not degrade significantly by itself. The vehicles that operate over the rails are the major cause of this deterioration. The present FAST consist was selected for a number of reasons; however, the major factor was that the mechanical design of car bodies and trucks were very similar to that used for the previous test periods. Thus, the only main variable would be the axle load, allowing back-to-back comparisons between previous FAST tests with the least number of input variables.

Review of the results to date indicates that some areas in the mechanical equipment side need additional investigation, along with long-term research and development. With the existing train, which is made up of equipment designed and built in the late 1960s, allowable defects in components, especially the wheels, must be investigated under direction of the Vehicle Track Systems Committee. These include:

- Size of allowable wheel flats
- Limits of out of round wheels
- Limits of allowable surface defects, such as spalls and shells

These items may lead directly to increases in dynamic loads into the track structure, especially at the rail and tie level. Limiting the allowable size of such defects could result in a significant increase in the life span of the rail, tie and fastener. The extent to which these loads are transferred to various components in the track structure is not fully documented; however, additional investigations are planned.

Alternative car and suspension designs also need to be investigated. By reducing the impact and dynamic loads into the track structure, life of track components could be increased. Areas in mechanical design that need to be investigated include:

- Evaluate the effect of reducing unsprung mass. With a larger wheel diameter (and subsequent heavier wheel mass) the HAL car is already at a disadvantage, when compared to the conventional car. Additional design work in the suspension area may help reduce this effect.

- Premium trucks, which not only improve curving performance but reduce vertical dynamic forces, have been and should be evaluated.

- The effect of axle spacing, articulated cars and other designs should be investigated. The existing HAL train applies vertical loads at specified truck and car axle spacings, which are different than that of "double stack" and other alternate car designs.

Summary of Limitations

The future investigations, for both track and mechanical components, are based on the results from the existing FAST loop configuration, train operating policies, track maintenance standards and equipment designs. The results must be reviewed with some specific limitations in mind. These were stated in detail during the introduction section, and apply to all FAST test results to date. Limitations of the current test suggest changes that may be included in future test programs. These include:

- Variable speeds, with resulting different overbalance and underbalance conditions on curves should be investigated.
- Since the HAL program has been conducted with equipment manufactured in the 1960s, new mechanical equipment technology, including suspension, truck design, and wheel spacing, will be evaluated.
- Traffic mix of FAST is all loaded traffic, with no light cars or empties. The percentage of HAL traffic on some revenue lines may not be a high percentage of the overall tonnage.
- FAST produces a relatively mild environment for in-train forces. The effects of heavy braking (air and dynamic), and results from train forces from slack run in, grades and speed changes have not been addressed. Such forces will play a role not only in mechanical component fatigue life, but in forces that must be absorbed by the track structure as well.
- The dry climate at FAST, coupled with the stiff subgrade, may have reduced some of the track degradation effects of the HAL train. Future investigations will include a "low modulus support" track segment that is intended to evaluate the effects that HAL has on track geometry retention.

FUTURE

The results of the 33- and 39-ton axle load experiment have been presented in this document. The ongoing extension, which is utilizing the same train configuration and operating modes, started in late 1990.

This extension is being operated primarily to address some of the specific areas of track components that indicated immediate improvement was needed. Two major areas in this category include turnouts and field welds. Other test areas, such as fatigue of rail, grinding and ballast life, did not exhibit a full life cycle during the initial 160 MGT, and additional operations will be required to complete experiment objectives. Finally, the performance of some components, although adequate, could still be improved. The installation of a full matrix of tests to evaluate new and improved fastening systems, ties, rail and other track components will allow the evaluation of such items to continue.

Future FAST/HAL investigations will need to incorporate advanced technology in mechanical equipment designs. The program goals will be to monitor the effects of such equipment on existing as well as other improved track components. This will allow the engineering staff to determine the effect that such designs will have, if any, on overall operating and maintenance costs of a Heavy Axle Load system.

APPENDIX B

1990 HEAVY HAUL WORKSHOP AND FAST/HAL PROGRAM DESCRIPTION OF EXPERIMENTS

DESCRIPTION OF EXPERIMENTS

Below is a summary of the experiments that have been implemented to meet the objective of the HAL Program.

Rail Performance Experiment

The Rail Performance Experiment is one of the major tests currently being performed at FAST. The objective of this experiment is to determine the effects of 39-ton axle loads on rail wear, rail defect occurrence and growth, corrugation occurrence, metal flow, and weld batter.

This test is concentrated on the high rail of the three main curves of the HTL. The lubrication of the outside rail dictates that fatigue tests occur in Sections 25 and 3. Rail wear testing is performed in Section 7 due to the dryness of the high rail.

Rails of varying cleanliness, chemistry, hardness, and profiles were installed to see how they affect the test parameters. Cleanliness pertains to the volume and type of inclusions in the steel; chemistry refers to the chemical make-up of the steel. The hardness of the rails varies from 269 Brinell (old standard practice) to 370 Brinell (in-line head hardened practice), and rail profile generally pertains to the crown radius of the rail head, *i.e.*, how round or how flat the rail head is.

Though most of the rail was new at the beginning of the test, some had previous exposure to traffic. This includes conditioned rails with 150 MGT of 33-ton axle load exposure and "dry break-in" rails with 15 MGT of nonlubricated 39-ton axle load exposure. Also, some of the new rail installed was the same type that was tested during the 100-ton car test. The 100-ton and the 125-ton test results on this particular rail can and will be compared with each other.

A special rail grinding/conditioned rail experiment is being performed in Section 25. This test consists of four test zones: (1) rail with 15 MGT of dry 39-ton axle load exposure, (2) rail with a profile ground to match a worn profile, (3) asymmetrically ground rail, and (4) rolled rail. This test will be used to determine whether rail fatigue life can be improved by conditioning the rail with dry exposure, grinding the profile for "artificial wear," or grinding an asymmetrical rail profile pattern to alter the wheel/rail contact geometry.

Tie and Fastener Experiment

The objective of the Tie and Fastener Experiment is to determine behavior and performance of concrete and wood ties, along with various types of rail fasteners in a heavy axle environment. The experiment includes three separate areas of investigation: (1) wood tie and fastener performance, (2) gage restraint ability, and (3) concrete tie and fastener performance.

Test zones are established in the 5- and 6-degree curves of the HTL. Measurements include track geometry, fastener stiffness, tie plate cutting, visual inspections of concrete ties, and dynamic rail loads and deflections.

The data will be analyzed to determine the behavior of the tie/fastener systems as a function of traffic accumulation (MGT) and compared to performance under the 100-ton consist.

The experiment also addresses the ability of wood ties with cut spike fasteners to maintain gage.

Measurements of dynamic lateral wheel force and lateral rail deflection will be taken at various locations on the HTL at various increments of MGT accumulation to characterize the dynamic performance of the various systems. The dynamic vertical and lateral wheel loading of the test zones will also be characterized on a regular basis.

Turnouts and Frogs

Early in the 100-ton test, turnouts were evaluated for component performance. A similar experiment is being conducted during the HAL phase with two #20 turnouts.

The experiment will measure the load environment, geometry degradation, vehicle response, and stiffness of the turnouts at specific levels of tonnage accumulation.

The by-pass track will permit operation on both sides of the turnouts, with a minimum of 20 percent of the traffic on the diverging side of the turnout. Since the traffic on the HTL is primarily unidirectional, one turnout is exposed to predominantly facing point movements and the other to trailing point traffic. Load data is collected through the turnouts using an instrumented wheel set and rail mounted strain-gage circuits. Dynamic lateral, vertical, and longitudinal rail deflections are taken at the point and heel of switch, and at the point of frog and guard rail area. Vertical and lateral track stiffness measurements are taken at selected points throughout the turnout.

A test of newer design turnouts using moveable point frogs and concrete ties may be also be implemented.

As part of the turnout and frog test, a "frog farm" was recently installed in the tangent track of Section 22. The five isolated frogs (frogs not in turnouts) consist of three railbound manganese and two European designed frogs. The objective of this test is to compare the performance characteristics of the frogs. Criteria include insert wear rates and maintenance time demanded. The inserts were radiographed prior to installation to determine inclusion and void content. These results will be used in performance evaluations.

Track Irregularity

The Track Irregularity Experiment is designed to determine track geometry degradation at rail profile irregularities such as battered welds and joints.

The affect of vehicle dynamics, specifically roll and bounce motions, on track degradation will be observed. The key parameters being measured are applied wheel loading as measured with an instrumented wheel set and rail mounted strain gage circuits, and track geometry. Supporting data includes longitudinal rail profile and vertical track stiffness.

Ballast Resistance Characterization

The Ballast Resistance Characterization Test will define the rate at which track lateral resistance as provided by the ballast section is restored with traffic, after disruption of the ballast section by maintenance.

Ballast Test

A comprehensive ballast experiment compares performance of granite, limestone, traprock, and dolomite ballasts, with results obtained during the 100-ton phase. A test zone of each ballast type is established on a 5-degree curve, and varies in length from 570 to 900 feet.

Each test zone contains approximately 8 inches of sub-base material between the subgrade and the ballast section, and a below tie ballast-depth of 12-15 inches at the low rail. Track geometry, loaded track profile, track settlement, sieve analysis, ballast density, and vertical track modulus are measured in each zone.

Ballast degradation, track strength, and track geometry are the parameters used to evaluate ballast performance as a function of MGT accumulation.

Subgrade Test

The potential for subgrade failure is one of the more troubling issues in evaluating track performance under heavy axle loads.

Available analytical models have not been validated for axle loads of 39-tons. One hypothesis predicts linear increases in subgrade pressures and deformations while another postulates a non-linear increase resulting in additional maintenance requirements. The potential for complete subgrade failure also exists.

To provide validation data, pressure cells and extensometers, which measure subgrade deflection, have been installed at two sites on the HTL. Test site is located on tangent track with slag ballast. The site is on a fill area with a below tie ballast depth of 18 inches.

Unlike the other HAL experiments, the 100-ton comparison is not based on early FAST data, but on subgrade pressures and deflections acquired during the final months of the 100-ton operation. This was done to obtain as closely as possible the same soil moisture and compaction levels between programs.

Mechanical Components Performance

During the initial stages of the HAL Program, a wheel wear evaluation will be conducted as a part of the Mechanical Component Performance Experiment. The objective is to determine the wear rate and fatigue behavior of the 38-inch, class C wheels expected to be used in revenue service with heavy axle loads. A few class C, 36-inch wheels with 33-ton axle loads will be inserted into the HAL consist for comparative purposes.

The test consist will include three HAL cars equipped with standard three-piece trucks, and three 100-ton cars equipped with standard three-piece trucks.

TRAIN OPERATION

A fleet of high side gondolas and covered hopper cars has been obtained and loaded to a gross vehicle weight on the rail of 315,000 pounds. To replicate the center of gravity typical of these cars in revenue service, the gondolas are loaded with a lightweight aggregate material with a density similar to coal and the covered hoppers filled with sand to simulate concrete.

Normally, the consist includes 65 to 85 HAL cars plus the three 100-ton cars of the Mechanical Components Test. Four or five 4-axle locomotives are used to power the train at a steady 40 mph, resulting in an overbalance condition of approximately 2 inches on the curves.

The train operates an average of three days per week, with two days set aside for track maintenance, and car inspection and repair. A typical day of train operation produces 1 MGT of tonnage on the track and 270 miles on the cars. Every 5 MGT, track geometry data is collected for experimental and maintenance purposes. An ultrasonic rail flaw inspection vehicle is operated at 3 MGT intervals.

The train operates in a counterclockwise direction on the loop, except for 30 laps every 3 MGT when the train is reversed. The reversal of direction alters the shape of rail defect growth rings, permitting accurate tracking of defect growth rates. Car orientation is reversed periodically to equalize wheel wear.

SUMMARY AND DESCRIPTION OF MEASUREMENTS

Measurements required by each experiment are conducted periodically, usually triggered by a specified accumulation of tonnage. The various measurements taken at FAST are as follows:

Rail Head Profile

The Yoshida rail head profilometer is used to record a 1:1 copy of the rail head profile.

Rail Hardness

Two measurement devices are used to measure Brinell and surface hardness at several points at the top of the rail head.

Tie Plate Cutting

The height of the tie plate relative to top of the tie is measured with a self indexing fixture.

Track Inspection

A walking inspection of all test zones is made every 1 MGT to 3 MGT.

Lateral/Vertical Rail Force

Dynamic vertical and lateral wheel loads are measured with strain gage circuits mounted on the web and base of the rail.

Dynamic Rail Deflection

Displacement transducers measure rail head and base lateral displacement relative to the tie.

Track Geometry

Track geometry is measured with an EM80 track geometry car.

Vertical Track Stiffness

A known vertical load is applied to the rail and the resultant vertical rail deflection measured.

Spike Pullout Resistance

A load cell is used to measure the force needed to pull the spike from the tie.

Single Tie Push Test

A load cell is used to measure the force needed to displace individual ties laterally through the ballast section.

Ballast Sieve Analysis

Gradation analysis of ballast per the ASTM C136 modified procedure.

Ballast Flakiness Indices

Classification of ballast particles having a thickness dimension less than 60 percent of nominal particle size.

Ballast Elongation Indices

Classification of ballast particles whose length is greater than 180 percent of nominal particle size.

CIGGT Shape Factor Test

Ballast particles retained on a specific sieve are measured for smallest width and longest dimension. Shape factor is the ratio of the sum of the longest dimension to the sum of the shortest width.

Ballast Density

A nuclear density probe is inserted into a steel pipe which has been installed through the tie and ballast to 3 inches above the subgrade/ballast interface to measure the ballast density.

Loaded Track Profile

The top of rail elevation is measured under the wheel of a fully loaded car.

Level Net

Top of tie elevation is taken immediately outboard of both rails. Tacks are used to ensure subsequent measurements are taken at the same location.

Subgrade Classification

Laboratory tests are performed in accordance with the ASTM D2487 standard to classify soil for engineering purposes.

Moisture Content

Laboratory tests are performed in accordance with the ASTM D2216 standard to determine the soil moisture content.

Liquid and Plastic Limit

The ASTM standards D423 and D424 are used to determine the liquid and plastic limits of the soil.

Instrumented Tie Plate

The rail seat load on wood ties is measured with instrumented tie plates which have been calibrated in track.

Dynamic Soil Measurements

The dynamic response of pressure cells and extensometers installed in the subgrade under the ties is monitored.

Static Soil Measurements

The measurement is accomplished by loading the track incrementally to a maximum of 50,000 pounds at each tie where subgrade pressure transducers have been installed.

Continuous Wheel Load Measurement

Instrumented wheel sets are utilized to measure vertical and lateral wheel loads, and axle torque.

Gage Widening

Static lateral and vertical loads are applied to both rails simultaneously producing a 0.5 L/V ratio, and the total lateral displacement of the rails are measured relative to the tie.

Longitudinal Rail Profile

A profilometer traces the rail head profile in the longitudinal direction for a length of 36 inches.

Goop Gage

A template is used to measure lubrication position on the gage side of the rail head.

Rail Flaw Monitoring

The rail is inspected for internal defects using ultrasonic equipment.

Rail Corrugation

Running surface degradation of rails and welds are monitored using the longitudinal rail profilometer.

Dynamic Corrugation

Strain gage circuits are mounted on the web of the rail to measure the load at the corrugation valley and the peak.

CN Profilometer and Snap Gage

A CN profilometer is used to collect wheel profile data and a TTC snap gage measures wheel area loss.

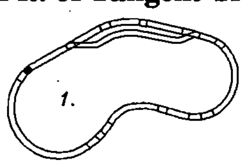
Metallurgical Evaluation

Selected rails and wheels exhibiting internal and/or surface defects are submitted to macroscopic inspection, metallography, hardness profiles, scanning electron microscopy and x-ray analysis.

DESCRIPTION OF HTL TRACK SECTIONS

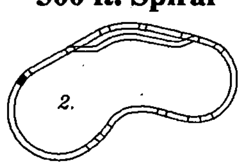
The typical HTL track structure consists of continuous welded rail fastened to wood ties with cut spikes and fully box anchored at every second tie. Included in specific test zones are concrete ties, jointed rail, and elastic type rail fasteners. A description of each section follows:

Section 1
171 ft. of Tangent Track



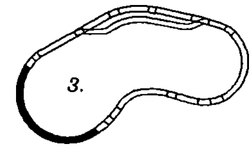
Transition zone/available for testing. Location of hot bearing detector.

Section 2
300 ft. Spiral



Transition zone/available for testing.

Section 3
3740 ft. of Track on a 5 Degree Curve



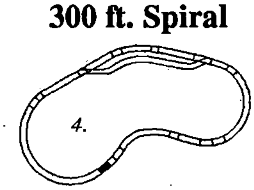
Location of Ballast, Rail Performance and Tie and Fastener Experiments.

Rail performance measurements include gage point wear, head height loss, metal flow, rail head profile, rail hardness, welded rail end batter, LRP, goop gage, rail flaw monitoring, wheel force data, track geometry, and corrugation.

Tie measurements include track geometry, rail fastener stiffness, rail loads, dynamic rail deflection, tie plate cutting, and static track gage.

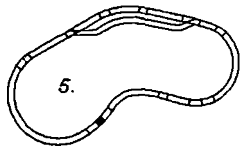
Ballast measurements include ballast sampling, particle indices, ballast gradations, loaded profiles, level net, ballast density, track geometry, and vertical track modulus.

Section 4
300 ft. Spiral



Transition zone/available for testing.

Section 5
224 ft. of Tangent Track



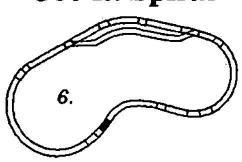
Location of Subgrade Experiment and Frog Casting Performance Test.

Measurements include static and dynamic subgrade pressure and deflection.

The subgrade material will be classified in the laboratory and tested for moisture content, liquid and plastic limits.

Location of hot bearing and acoustic bearing detector.

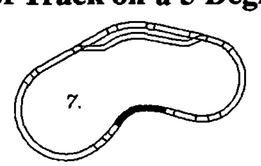
Section 6
300 ft. Spiral



Location of Ballast Resistance Characterization Test.

Measurements include lateral ballast resistance as measured with the single tie push test.

Section 7
1002 ft. of Track on a 5 Degree Curve

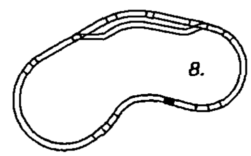


Location of Tie and Fastener and Rail Performance Experiments.

Tie measurements include tie plate cutting, fastener stiffness, rail loads, dynamic rail deflections, track geometry, and static track gage.

Rail wear measurements include gage point wear, head height loss, metal flow, rail head profile, rail hardness, welded rail end batter, LRP, and rail flaw monitoring.

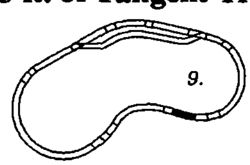
Section 8
300 ft. Spiral



Location of Ballast Resistance Characterization Experiment.

Measurements include lateral ballast resistance as measured with the single tie push test.

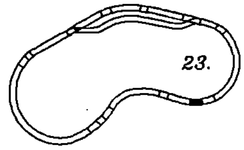
Section 9
313 ft. of Tangent Track



Road crossing and #10 turnout.

Proprietary test of uncased 12 inch and 36 inch pipes buried under railroad track.

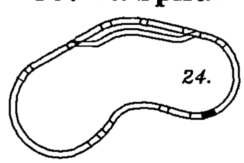
Section 23
164 ft. of Track on a 1 Degree-45 Minute Curve
and
201 ft. of Tangent Track



Frog Casting Performance Test.

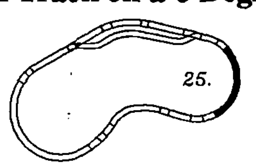
Wayside rail lubricator.

Section 24
300 Ft. Spiral



Transition zone/available for testing.

Section 25
2692 ft. of Track on a 6 Degree Curve

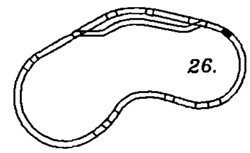


Location of Rail Performance, Ballast Resistance Characterization and Tie and Fastener Experiments.

Tie measurements include tie plate cutting, fastener stiffness, rail loads, dynamic rail deflections, track geometry, and static track gage.

Rail performance measurements include gage point wear, head height loss, metal flow, rail head profile, rail hardness, welded rail end batter, LRP, rail flaw monitoring, goop gage, track geometry, wheel force data and corrugation.

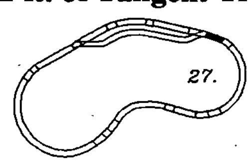
Section 26
300 ft. Spiral



Location of Tie and Fastener Experiment.

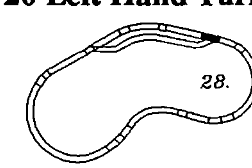
Measurements include static gage widening.

Section 27
332 ft. of Tangent Track



Location of Frog Casting Performance test.

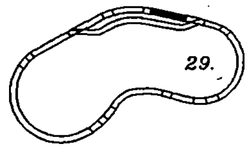
Section 28
#20 Left Hand Turnout



Location of Turnout Experiment.

Measurements include rail/wheel loads, dynamic rail deflections, lateral and vertical rail stiffness and track geometry.

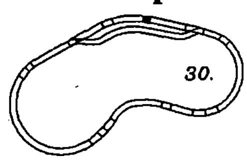
Section 29
987 ft. of Tangent Track



Location of Track Irregularity Experiment

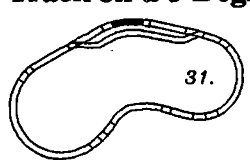
Measurements include rail/wheel loads, dynamic rail deflections, vertical track stiffness and track geometry.

Section 30
300 ft. Spiral



Transition zone/available for testing.

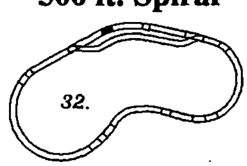
Section 31
511 ft. of Track on a 5 Degree Curve



Location of Tie and Fastener Test.

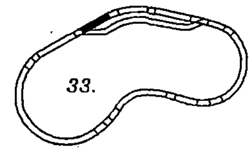
Measurements include tie plate cutting and track geometry.

Section 32
300 ft. Spiral



Transition zone/available for testing.

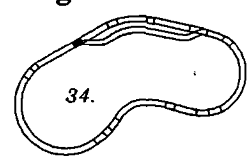
Section 33
517 ft. of Tangent Track



Location of Ballast Resistance Characterization Experiment and Frog Casting Performance Test.

Measurements include lateral ballast resistance as measured with the single tie push test.

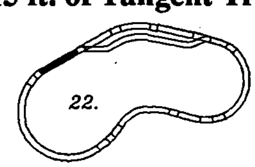
Section 34
#20 Right Hand Turnout



Location of Turnout Experiment.

Measurements include rail/wheel loads, dynamic rail deflections, lateral and vertical rail stiffness, and track geometry.

Section 22
715 ft. of Tangent Track

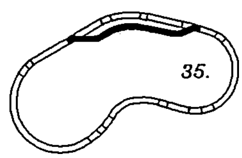


Location of Ballast Resistance Characterization Experiments and Frog Farm Test.

Measurements include lateral ballast resistance as measured with the single tie push test.

Frog Farm Test measurements include Brinell hardness and cross section profiles of the frogs.

Sections 28B - 34B
By-pass Track
1187 ft. of tangent track, 2 - 300 foot spirals, and 511 ft. of track on a 5 degree curve



Location of the Ballast Resistance Characterization Experiment.

Measurements include lateral ballast resistance as measured with the single tie push test.

DATA COLLECTION AND REPORTING

The various data are collected on magnetic tape/disk or recorded manually on a data form, then transferred to a data base on TTC's mainframe computer. All the dynamic data collected under the train is saved in digital format; the digitizing frequency being 1000-1500 samples per second. The tracings from the different profilometers are also digitized as XY coordinates to permit computer generated profile shapes and the computation of area loss. The track geometry data is digitized at one sample per foot of track.

Interim reports describing progress of the various experiments will be issued, along with a final report. These reports will be published by the FAST program and information as to their availability can be obtained through the FRA program office -- (202) 366-0464.

During the time the experiments are active, the TTC staff is planning to host several "open house" seminars so that interested parties can visit TTC and receive an up-to-date assessment of experiment progress, including a walking tour of the HTL. The seminar schedules will be published in the various railroad trade journals. If more information is required, interested parties should contact the FAST Program Manager at (719) 584-0581.

SAFETY CONSIDERATIONS

High volume, high mileage train operation can be very informative, but must be conducted safely. To ensure safety of personnel and equipment, visual inspections of the consist and car components are performed on a regular basis. All safety procedures comply with the AAR and FRA safety standards as appropriate.

The safety oriented measurements are as follows:

Wheels

Every car and locomotive wheel is measured for flange thickness, flatness and height, and rim thickness. Visual inspections are made to detect cracked or broken flanges; thermal cracks in flange, tread or plate; built-up, grooved, shelled or slid-flat treads; cracked, broken, burnt, shattered or spread rims; overheated wheels; cracked or broken plates or hubs.

Axle Journal Roller Bearings

The journal roller bearings are checked for grease loss, and loose or missing cap screws.

Roller Bearing Adapters

During regular shop maintenance, safety checks are made for adapter crown wear, pedestal roof wear above the adapter, thrust shoulder wear, and machined relief wear.

Trucks

Friction castings, side frames, and bolsters are checked for deterioration.

Air and Hand Brake

Train crews check for cracked or bent pipes, fittings and valves; defective or loose hoses; broken shoe keys; piston travel and inoperative air brakes; inoperative hand brakes; and worn brake beams, levers, guides, or bends.

Miscellaneous Components

Minimum standards examinations of running boards, brake steps, sill steps, handholds, ladders, center sill, body bolsters and structural welds are conducted.

Center Plates

During regular maintenance periods, crews check for vertical wall wear on both body and truck plates, horizontal surface wear and vertical linear weld cracks on the truck center plate. In addition to the regular maintenance intervals, inspections are required for body center plate cracks and weld connection cracks.

Side Bearings

Inspections are conducted for required side bearing clearances, cracks in the truck side bearing cages, wear in the body side bearing wear-plates and loose or bent body side bearing bolts.

Brake Shoes

Inspections are made prior to operation for cracks, breaks or excessively worn shoes.

Coupler and Carrier Wear Plates

Coupler shank plates and carriers are checked for cracks.

Couplers

During regularly scheduled maintenance, head and knuckles, shank length, butt thickness, knuckle wear, and draft key wear are checked to ensure the components meet minimum standards. Coupler body and shank are checked for cracks, bends, and breaks.

General

A hot bearing/hot wheel detector unit is utilized to monitor the train during each pass around the loop. The locomotives are also equipped with radio communication to advise the crew if a shutdown is necessary.

A broken rail detector system utilizing a modified track circuit system is in constant operation to detect broken or separated rails. This system is also detects improperly lined switches.

FAST/HAL Tie and Fastener Experiments,
1991
Association of American Railroads, Dave Read

ASSOCIATION OF AMERICAN RAILROADS

U.S. Department of Transportation

Federal Railroad Administration