FAST/HAL TRACK LOADS EVALUATION

AAR REPORT R-791
FRA/ORD-91/20

ASSOCIATION OF AMERICAN RAILROADS

U.S. Department of Transportation
Federal Railroad Administration

Facility for Accelerated Service Testing Heavy Axle Load Program

FAST/HAL TRACK LOADS
EVALUATION

AAR REPORT R-791
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by

David M. Read and Duane E. Otter

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13. Abstract

The FAST/HAL Track Loads Evaluation was conducted to quantify vertical and lateral forces at the Facility for Accelerated Service Testing, Transportation Test Center, Pueblo, Colorado, under 33- and 39-ton axle load cars. Vertical rail forces beneath the 39-ton axle load cars were found to be 25 percent to 35 percent higher than those beneath the 33-ton axle load cars. Lead axle lateral rail forces were from 13 percent to 28 percent higher under the 39-ton axle load cars. There were no significant differences in lateral to vertical force (L/V) ratios. The lateral forces and L/V ratios for both the 33- and 39-ton axle load cars were found to be dependant upon lubrication conditions. Corrugated rail was found to induce higher vertical forces than rail with no visible surface defects.

The vertical and lateral force measurements were taken using instrumented rail circuits at two separate locations in 5-degree curves. The loads were measured beneath a train of 14 each of 33- and 39-ton axle load cars which was operated at 40 mph to 42 mph. In addition, a pair of instrumented wheel sets was installed in a 39-ton axle load car to measure vertical and lateral forces. The measurements taken with the instrumented wheel sets generally supported those taken at the wayside locations.

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EXECUTIVE SUMMARY

The FAST/HAL Track Loads Evaluation was conducted to quantify vertical and lateral forces at the Facility for Accelerated Service Testing, Transportation Test Center, Pueblo, Colorado, under 33- and 39-ton axle load cars. Vertical rail forces beneath the 39-ton axle load cars were found to be 25 percent to 35 percent higher than those beneath the 33-ton axle load cars. Lead axle lateral rail forces were from 13 percent to 28 percent higher under the 39-ton axle load cars. There were no significant differences in lateral to vertical force (L/V) ratios. The lateral forces and L/V ratios for both the 33- and 39-ton axle load cars were found to be dependant upon lubrication conditions. Corrugated rail was found to induce higher vertical forces than rail with no visible surface defects.

The vertical and lateral force measurements were taken using instrumented rail circuits at two separate locations in 5-degree curves. The loads were measured beneath a train of 14 each of 33- and 39-ton axle load cars which was operated at 40 mph to 42 mph. In addition, a pair of instrumented wheel sets was installed in a 39-ton axle load car to measure vertical and lateral forces. The measurements taken with the instrumented wheel sets generally supported those taken at the wayside locations.

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1.0 INTRODUCTION

Vertical forces on the rail are the sum of the static wheel load plus dynamic forces caused by track geometry imperfections, vehicle dynamics, or by irregularities in the wheel and rail running surfaces. Lateral rail forces are comprised of vehicle curving forces, which includes truck steering and centrifugal forces, and dynamic forces induced by track geometry imperfections. The most significant lateral forces are those developed by the curving of a conventional three-piece truck due to truck steering, which produces gage spreading forces that are generally higher at the leading axle of each truck.

Determination of the vertical and lateral rail force environment contributes to the understanding of track and track component behavior and is a fundamental aspect of Heavy Axle Load (HAL) testing at the Facility for Accelerated Service Testing (FAST) -- see Appendix A. The test was designed to measure dynamic force data at two 5-degree curve locations on the High Tonnage Loop (HTL) under a train with equal numbers of 33- and 39-ton axle load cars. Vertical and lateral rail forces were measured with instrumented rails during 10 consecutive passes of the mixed consist train at speeds of 40-42 mph. In addition to the rail forces measured with a wayside instrumentation system, continuous vertical and lateral wheel forces were also measured with instrumented wheel sets installed in a 39-ton axle load car.

2.0 OBJECTIVE

The objective of the FAST/HAL Track Loads Evaluation was to determine dynamic rail forces generated at FAST by 33- and 39-ton axle load cars operating at a nominal speed of 40 mph. A secondary objective was to collect continuous wheel force data on curved and tangent track under a 39-ton axle load car.

3.0 PROCEDURES

Two locations on the HTL, each in the body of a 5-degree curve, were instrumented to measure lateral and vertical forces at the rail (Figure 1). Measurement location No. 1 was in Section 03, about 700 feet from the point of circular curve, and measurement location No. 2 was in Section 07, about 550 feet from the point of circular curve. At both locations the actual superelevation was 3.5 inches (design superelevation is 4.0 inches at both

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locations), which at test speeds of 42 mph, equates to 2.5 inches of superelevation deficiency. Track geometry (profile, alignment, and cross level) at both sites was free of significant or obvious deviations during collection of the force data. There were no irregularities in the top of rail running surface at the Section 03 measurement site; however, the high and low rails at the Section 07 site were corrugated. Depth of the corrugations, as measured under a 36-inch straightedge, was about 0.050 inches and the corrugation wavelength was nominally 12 inches.

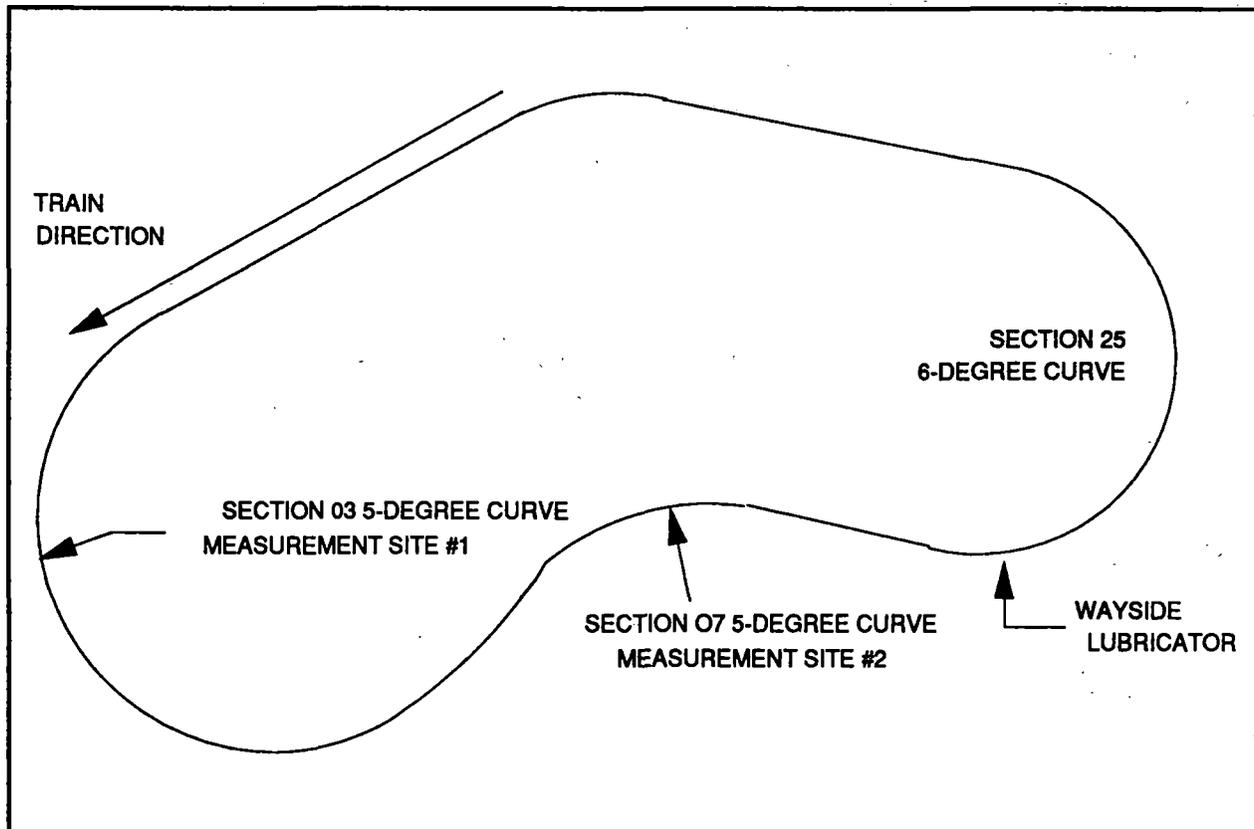**Figure 1. Location of Rail Force Measurement Sites**

During the test, the outside rail of the HTL, which was the high rail in Section 03 and the low rail in Section 07, was lubricated by a wayside lubricator at the beginning of the 6-degree curve in Section 25 (Figure 1). Because rail lubrication influences lateral forces, wheel/rail coefficient of friction was measured at both sites using the TTC tribometer.

Rail lubrication was consistent throughout the test and is summarized in Table 1 where the average wheel/rail coefficient of friction values measured at each site are listed. The data shown in Table 1 are representative of the rail lubrication conditions normally found in Sections 03 and 07.

Table 1. Average Wheel/Rail Coefficient of Friction Values

	Low Rail Top	Low Rail Gage Face	High Rail Top	High Rail Gage Face
Sect. 03	0.45	NA	0.33	0.20
Sect. 07	0.36	NA	0.50	0.35

The test train consisted of 14 cars with gross vehicle weights of 315,000 pounds (39-ton axle loads) followed by 14 cars with gross vehicle weights of 263,000 pounds (33-ton axle loads). The 33-ton axle load cars were all open top hopper cars, which were used during the 100-ton phase of testing at FAST. The 39-ton axle load cars were a mixture of high side gondola cars and covered hopper cars from the regular HAL train. The gondola cars and open top hopper cars were loaded with expanded shale -- a lightweight aggregate material very similar in density to coal. The covered hopper cars were loaded with sand to simulate their usual revenue loads of cement. All cars were equipped with three-piece trucks of various manufacturers and double roller type side bearings. The train operated only in the counterclockwise direction during the test.

Rail forces were measured with rail-mounted (wayside) strain gage instrumentation and a digital data collection system. Vertical forces were measured with strain gage circuits installed at the rail web and sensitive to vertical shear of the rail between two ties. A chevron circuit installed on the rail base at the same location as the vertical circuit was used to measure lateral forces. Both the vertical and lateral rail force circuits were developed early in the FAST program and are described in Reference 1. Each measurement site included a single vertical and lateral circuit on both high and low rails. Output of all circuits was calibrated in the track using the TTC Rail Force Calibration Car (605 car) which

applied known vertical and lateral forces to the rail. The vertical circuits were calibrated to a force of 40,000 pounds and the lateral circuits to a force of 20,000 pounds while under maximum vertical force. The collection system acquired data in a digital format at a rate of 1,024 samples per second.

The wayside rail force data was collected in October 1989 when FAST/HAL had accumulated about 85 million gross tons (MGT) of traffic.

Continuous wheel force data was collected in November 1989 after accumulation of 106 MGT of FAST/HAL traffic. Two 38-inch instrumented wheel sets were installed in a conventional three-piece truck of a 39-ton axle load car, and wheel force data was collected around the HTL at a nominal speed of 40 mph.

The instrumented wheel sets used in the test employ multiple strain gage circuits on each wheel to provide a continuous measurement of vertical, lateral, and longitudinal forces at the wheel/rail interface. The instrumented wheel sets are similar to those described in Reference 2. The data was taken at roughly 1 foot intervals along the track, representing a frequency of about 50 Hz.

4.0 DATA ANALYSIS
4.1 ANALYSIS OF VERTICAL RAIL FORCE DATA

Rail force data was processed to determine peak vertical and lateral forces produced by each wheel crossing each circuit. Figures 2 and 3 show the distributions of peak vertical forces, excluding the locomotives, produced during 10 passes of the train in Sections 03 and 07. The distributions are plotted as the percentage of wheel forces exceeding a given force value. Both plots include distributions of vertical forces for the 33- and 39-ton axle load cars on the high and low rails of the curves and show a consistent increase in dynamic forces relative to increased axle weight at all percentile levels.
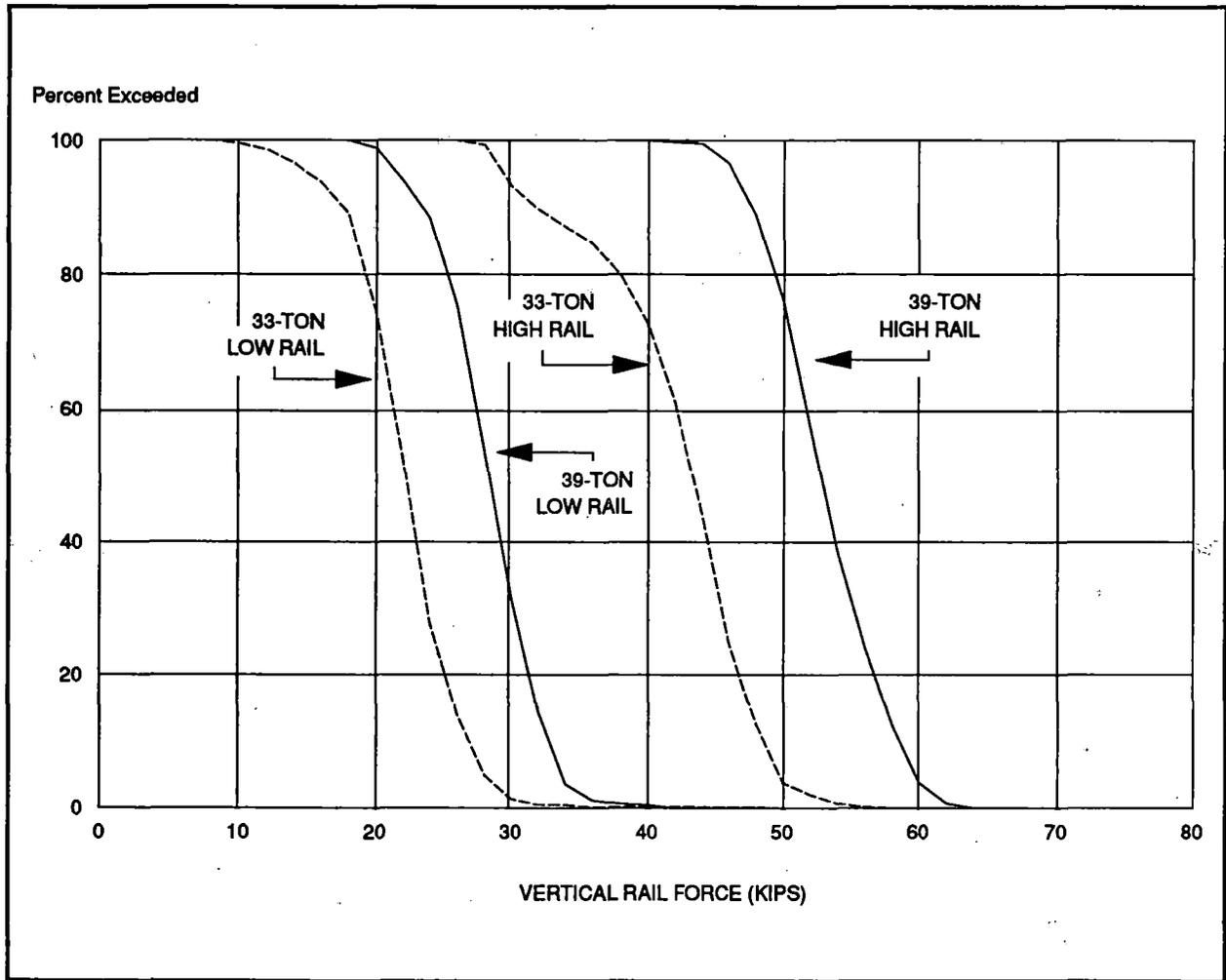
Figure 2. Vertical Force Distributions for Section 03

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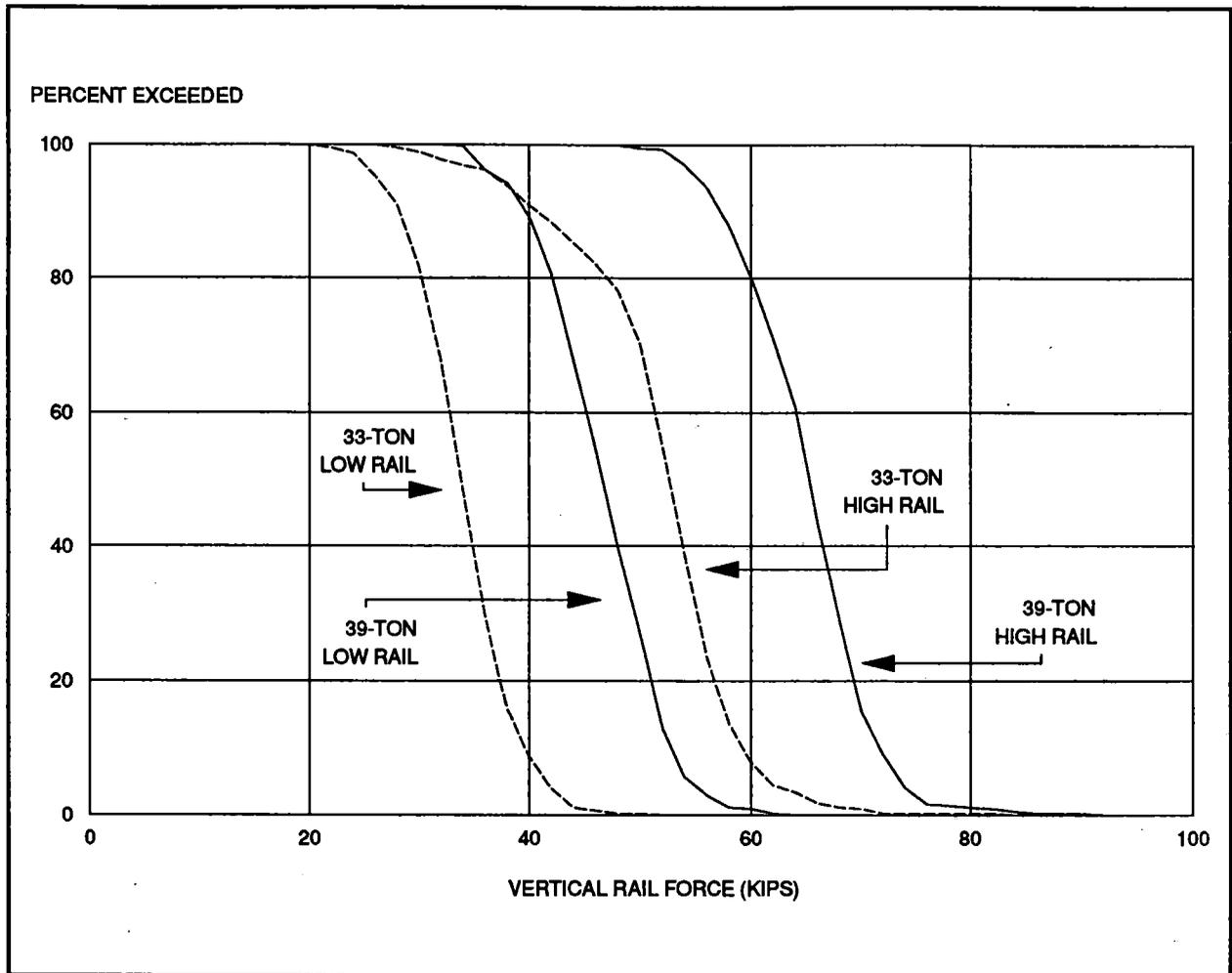
Figure 3. Vertical Force Distributions for Section 07

In addition to showing the effects of increased axle loads on vertical rail forces, the data collected in Section 07, when compared to the Section 03 data, also gives an indication of vertical force input at the rail due to rail corrugations. The force distribution curves in Figure 3 (Section 07) are clearly higher at all percentile levels than the curves in Figure 2 (Section 03). To illustrate the overall force increase caused by the corrugated rail surface, high rail vertical forces generated by 39-ton axle load cars in Sections 03 and 07 are compared in Figure 4. The increase in force values in Figure 4 is about 24 percent. Similar section-to-section comparisons of 33-ton axle load cars on the high and low rails show

increases in vertical rail forces due rail corrugations of about the same magnitude. Wayside force data collected at different locations on the same (corrugated) rail as part of the Rail Wear Experiment showed similar results.[3]

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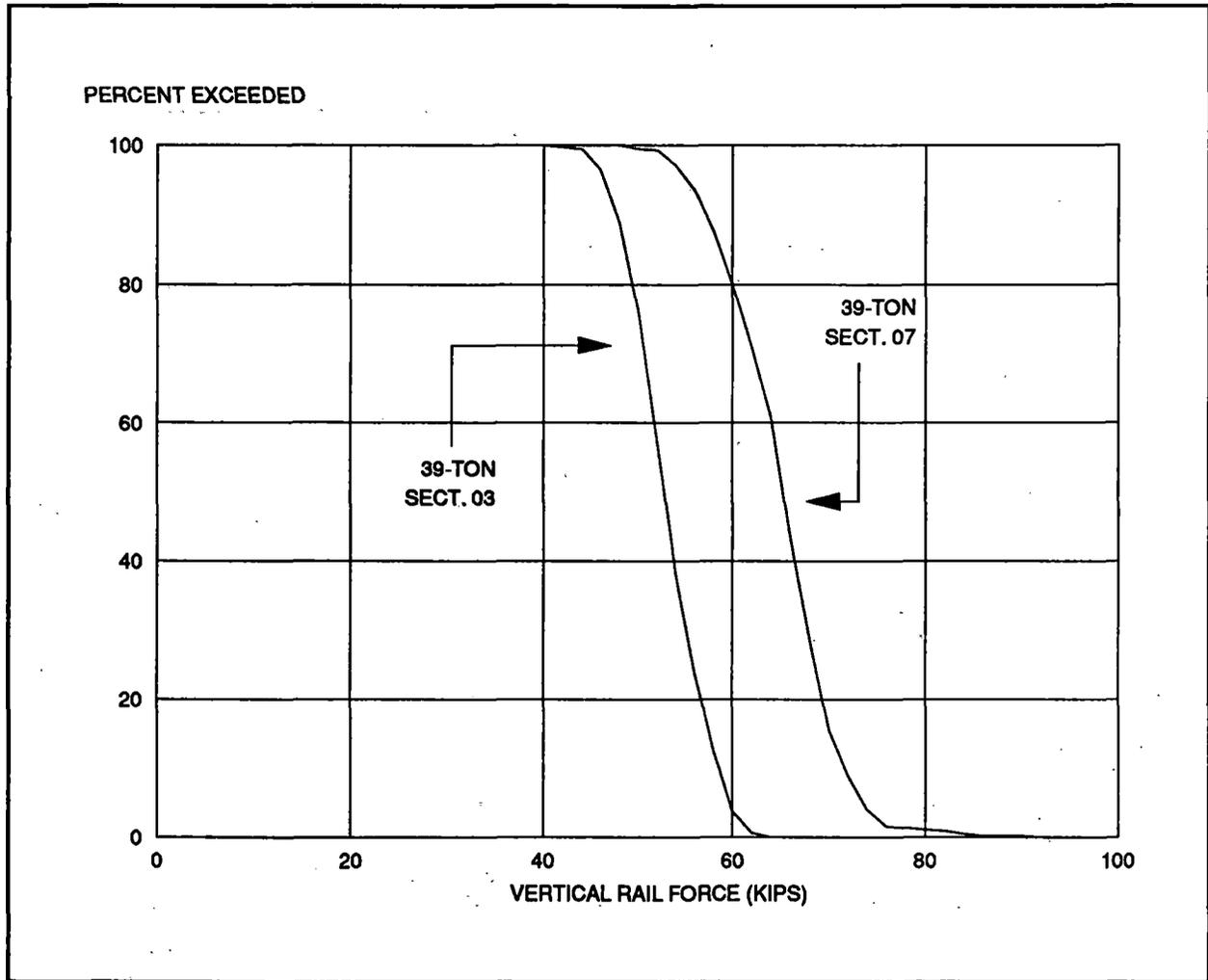
Figure 4. High Rail Vertical Forces for Sections 03 and 07

4.2 ANALYSIS OF LATERAL RAIL FORCE DATA

Distributions of peak lateral rail forces measured at the leading axles are shown in Figures 5, 6, and 7. The lateral rail forces generated by the trailing axles of either car type were found to be typically less than the lateral rail forces generated by the leading axles, and therefore the trailing axle lateral forces are not included in the comparisons.
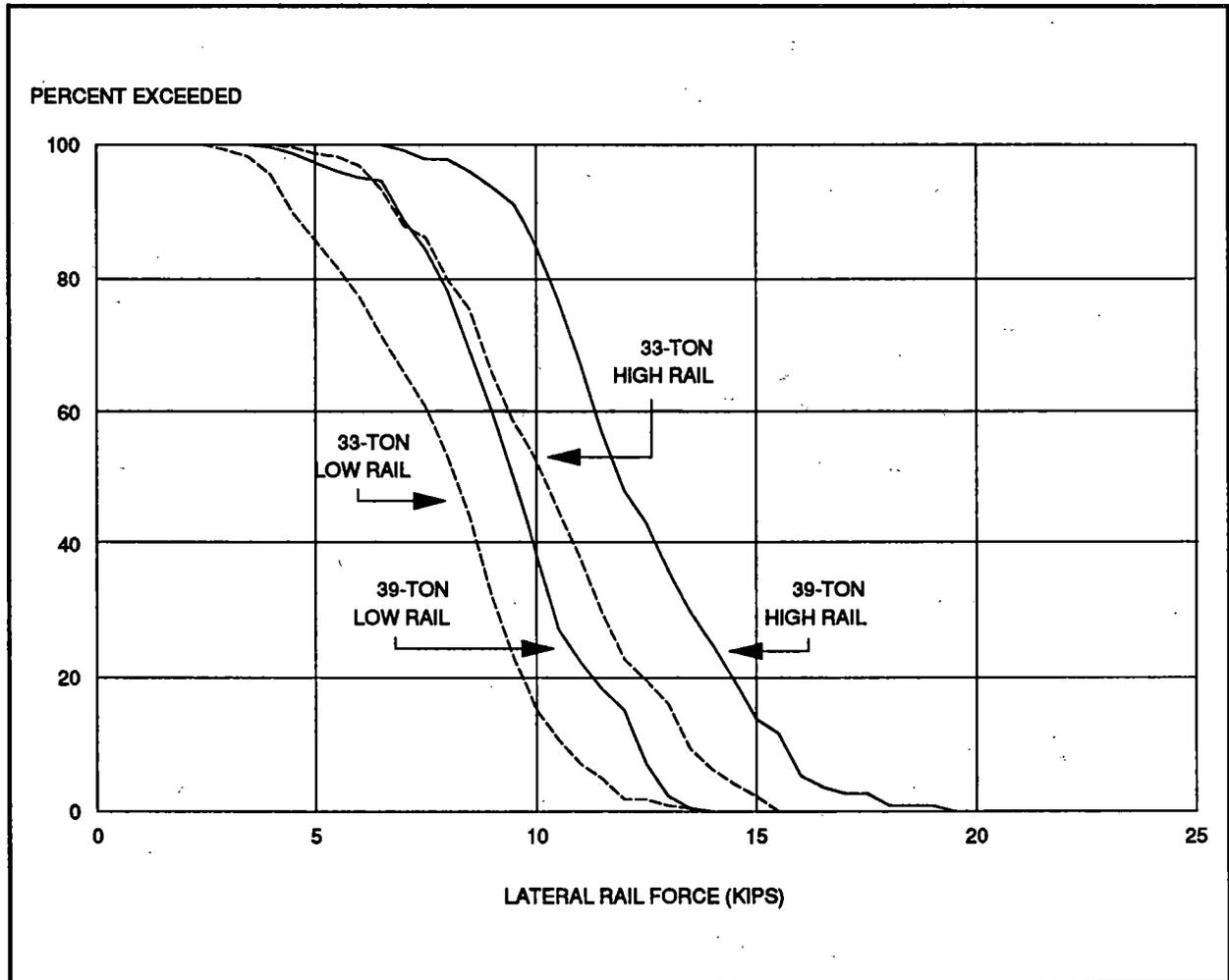
Figure 5. Lead-Axle Lateral Force Distributions for Section 03
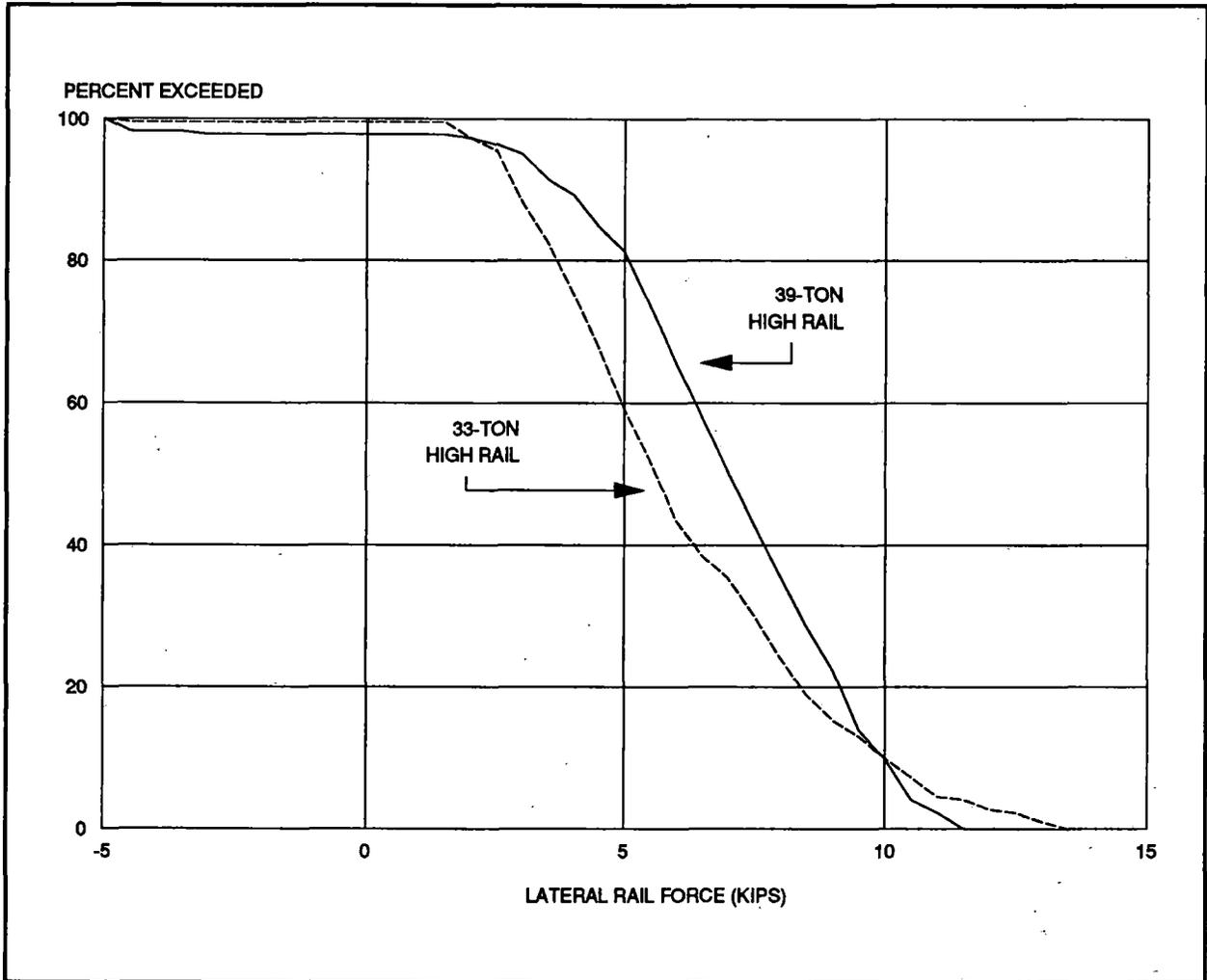
Figure 6. High Rail Lead-Axle Lateral Force Distributions for Section 07

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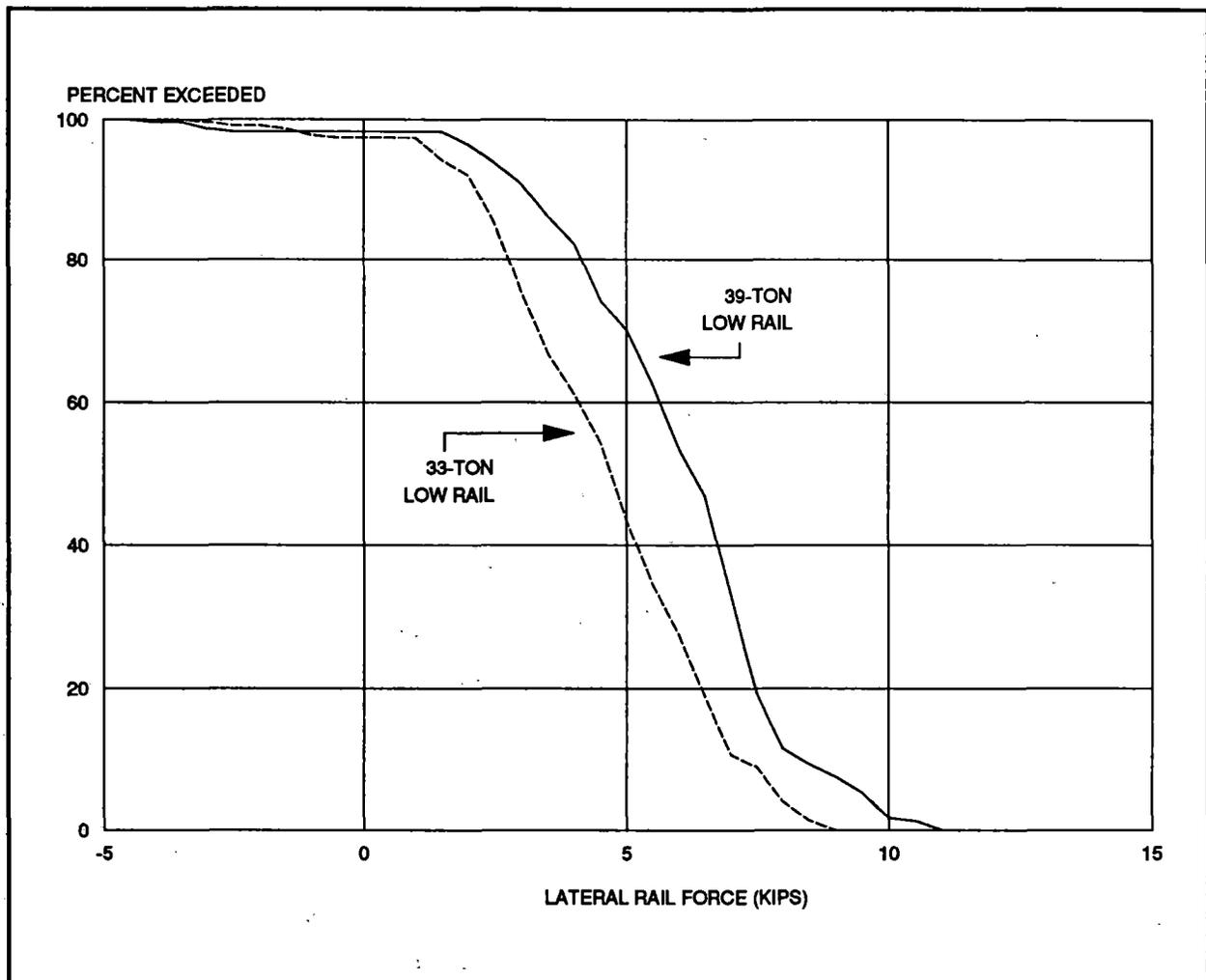
Figure 7. Low Rail Lead-Axle Lateral Force Distributions for Section 07

The lateral to vertical force (L/V) ratio was computed from the data base for the lead axle wheels at each measurement site. In Figures 8 and 9, the distributions of lead axle L/V ratios are plotted for Sections 03 and 07 respectively. The critical information conveyed in these two figures is that the L/V ratios at the two sites were not significantly different for the 33- and 39-ton axle load vehicles. Note also that although the lead axle lateral forces were slightly lower on the low rail, the L/V ratios are higher on the low rail. This is due to the superelevation deficiency and the resulting lower vertical forces on the low rail. The trailing axle L/V ratios were generally less than the leading axle L/V ratios.
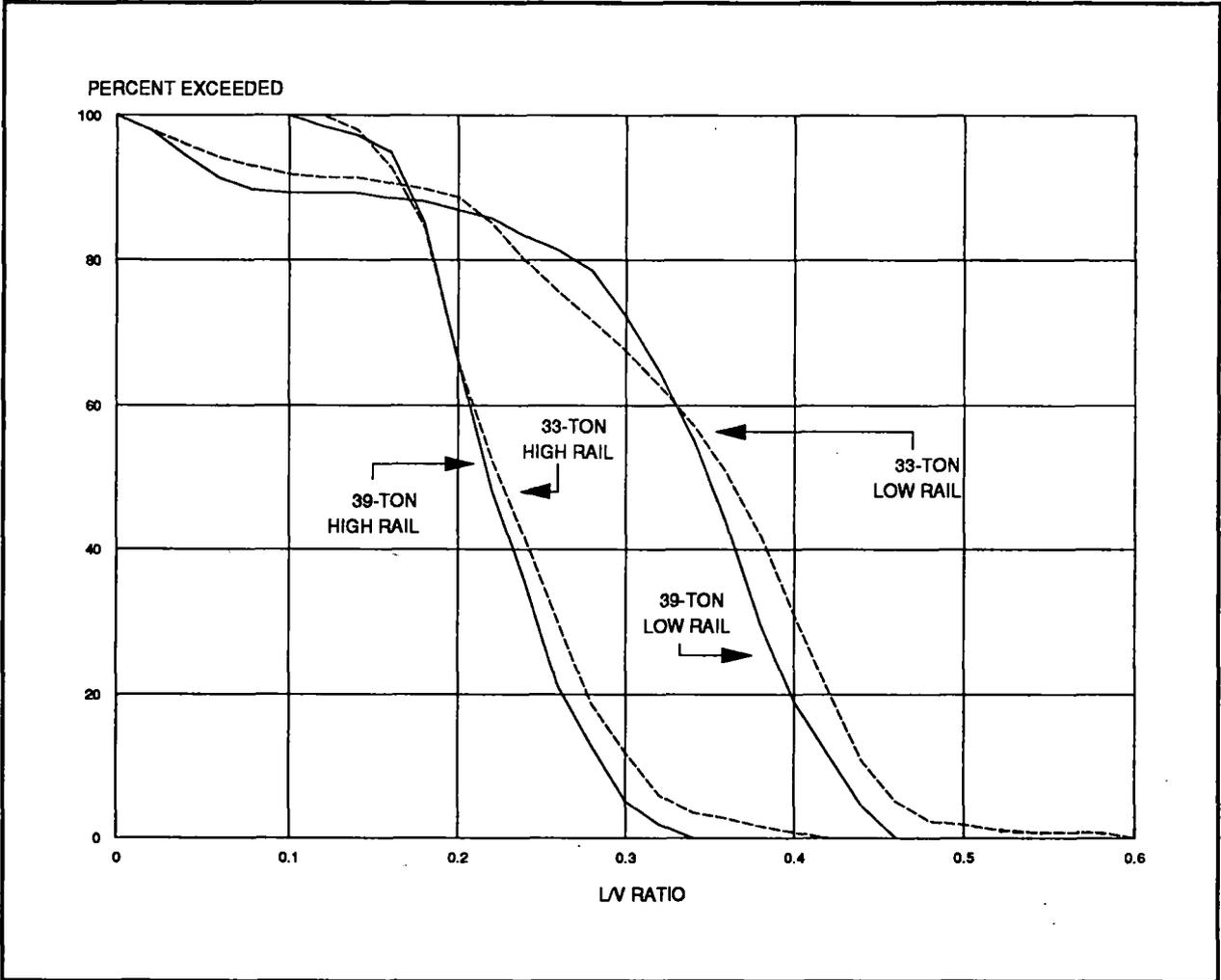
Figure 8. Distributions of Lead-Axle L/V Ratios for Section 03

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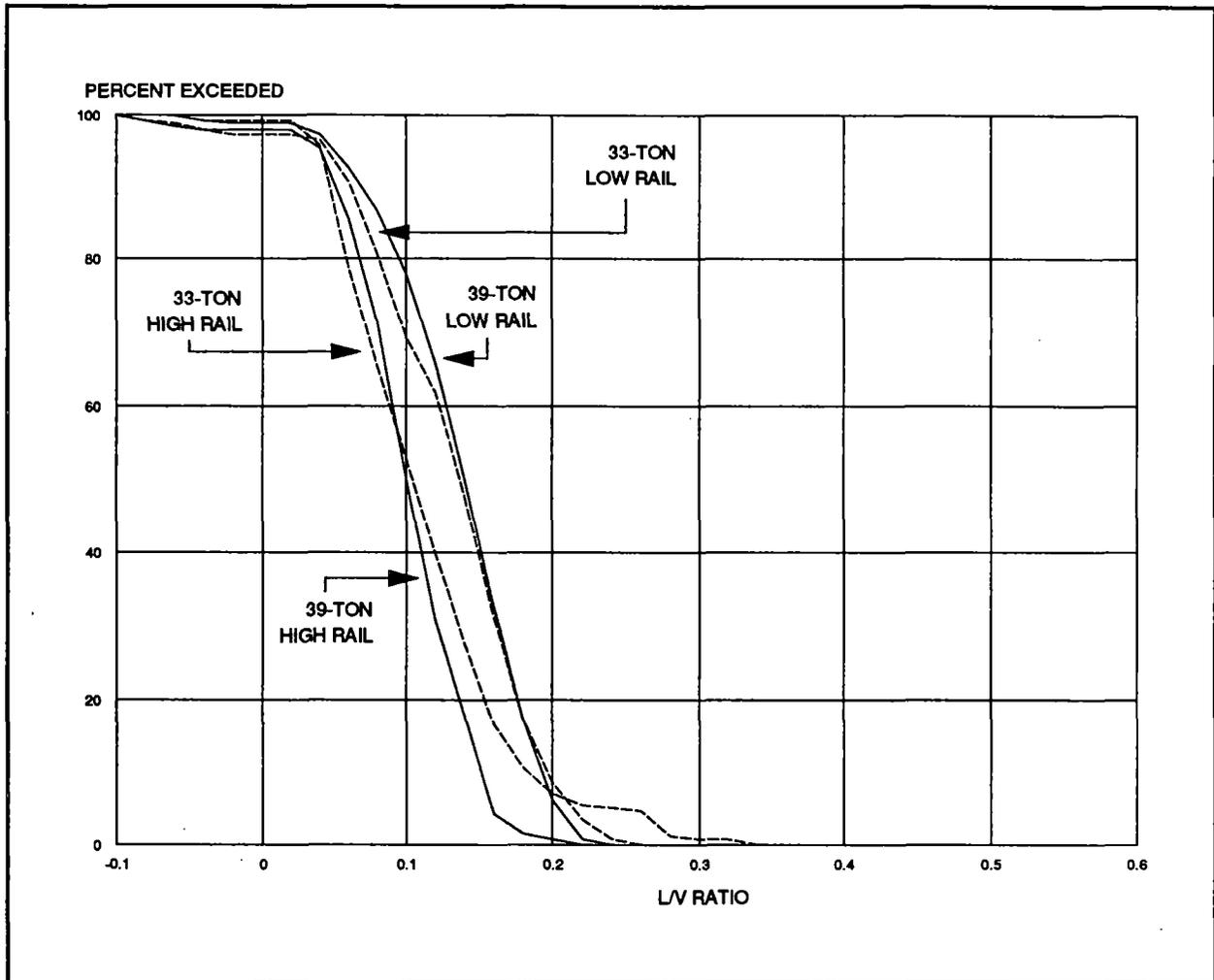
Figure 9. Distributions of Lead-Axle L/V Ratios for Section 07

The rail force and L/V data are summarized for both measurement sites in Tables 2 and 3. Both tables list the average and 95th percentile force and ratio values recorded during the test. The tables also indicate the difference in the 33- and 39-ton force values as a percentage of the 33-ton force value.

Table 2. Summary of Section 03 Rail Force and L/V Values

SECTION 03 FORCES (KIPS)	33 TON	39 TON	% INCREASE
Average Vertical High Rail	42	53	26
95th Percentile Vertical High Rail	49	59	20
Average Vertical Low Rail	22	28	27
95th Percentile Vertical Low Rail	28	34	21
Average Lead Lateral High Rail	10.2	12.3	21
95th Percentile Lead Lateral High Rail	14.5	16	10
Average Lead Lateral Low Rail	7.9	9.4	19
95th Percentile Lead Lateral Low Rail	11.5	12.5	9
Average Lead L/V High Rail	0.23	0.22	*
95th Percentile Lead L/V High Rail	0.32	0.30	*
Average Lead L/V Low Rail	0.33	0.32	*
95th Percentile Lead L/V Low Rail	0.46	0.42	*

* No significant differences due to axle loading.

Table 3. Summary of Section 07 Rail Force and L/V Values

SECTION 07 FORCES (KIPS)	33 TON	39 TON	% INCREASE
Average Vertical High Rail	52	65	25
95th Percentile Vertical High Rail	62	74	19
Average Vertical Low Rail	34	46	35
95th Percentile Vertical Low Rail	42	54	29
Average Lead Lateral High Rail	6.0	6.8	13
95th Percentile Lead Lateral High Rail	11.0	10.5	*
Average Lead Lateral Low Rail	4.6	5.9	28
95th Percentile Lead Lateral Low Rail	7.7	9.5	23
Average Lead L/V High Rail	0.13	0.13	*
95th Percentile Lead L/V High Rail	0.21	0.21	*
Average Lead L/V Low Rail	0.11	0.10	*
95th Percentile Lead L/V Low Rail	0.24	0.16	*

* No significant differences due to axle loading.

Tables 2 and 3 show that lower lateral forces and L/V ratios were recorded in Section 07 as compared to Section 03. The lower lateral forces in Section 07 can be partially attributed to rail lubrication differences between the two sites. The wheel/rail coefficient of friction measured on the top of the low rail head in Section 07 was 25 percent less than the low rail top-of-rail head coefficient of friction in Section 03 (Table 1). Experimental work performed by Laine and Wilson[4] after a derailment at FAST in 1986, determined that small amounts of lubricant added to top of the low rail reduced lateral rail forces.

Tables 2 and 3 also show that higher vertical rail forces were recorded in Section 07 than in Section 03. As mentioned earlier, the vertical force disparity is probably due to rail corrugations present in Section 07 at the time of the test.

Another possible reason for the differences, and a basic limitation of wayside force measurements in general, is the site specific nature of the data. Because it is collected at a discrete point on the track, wayside data is influenced by local irregularities and car dynamics which may or may not be typical of the overall force behavior.

4.3 ANALYSIS OF INSTRUMENTED WHEEL SET DATA

Continuous wheel force measurements from instrumented wheel sets complement way-side rail force measurements and enhance knowledge of the applied vertical and lateral force environment. Because instrumented wheel sets quantify wheel forces generated by a single vehicle traveling over a length of track, the data is particularly valuable since it provides information about dynamic behavior of the vehicle.

The lead axle forces measured through about 700 feet of Section 03 are shown in Figure 10. Figure 11 shows the trailing axle forces. Note that the vertical forces at the high rail are greater than those at the low rail due to the over balanced speed operation and that the lateral forces are higher on the leading axle than on the trailing axle, as mentioned earlier. The vertical forces, however, are about the same for both the lead and trail axles. Note also, the cyclic nature of the vertical wheel force data indicating car roll dynamics as it traveled through the curve.
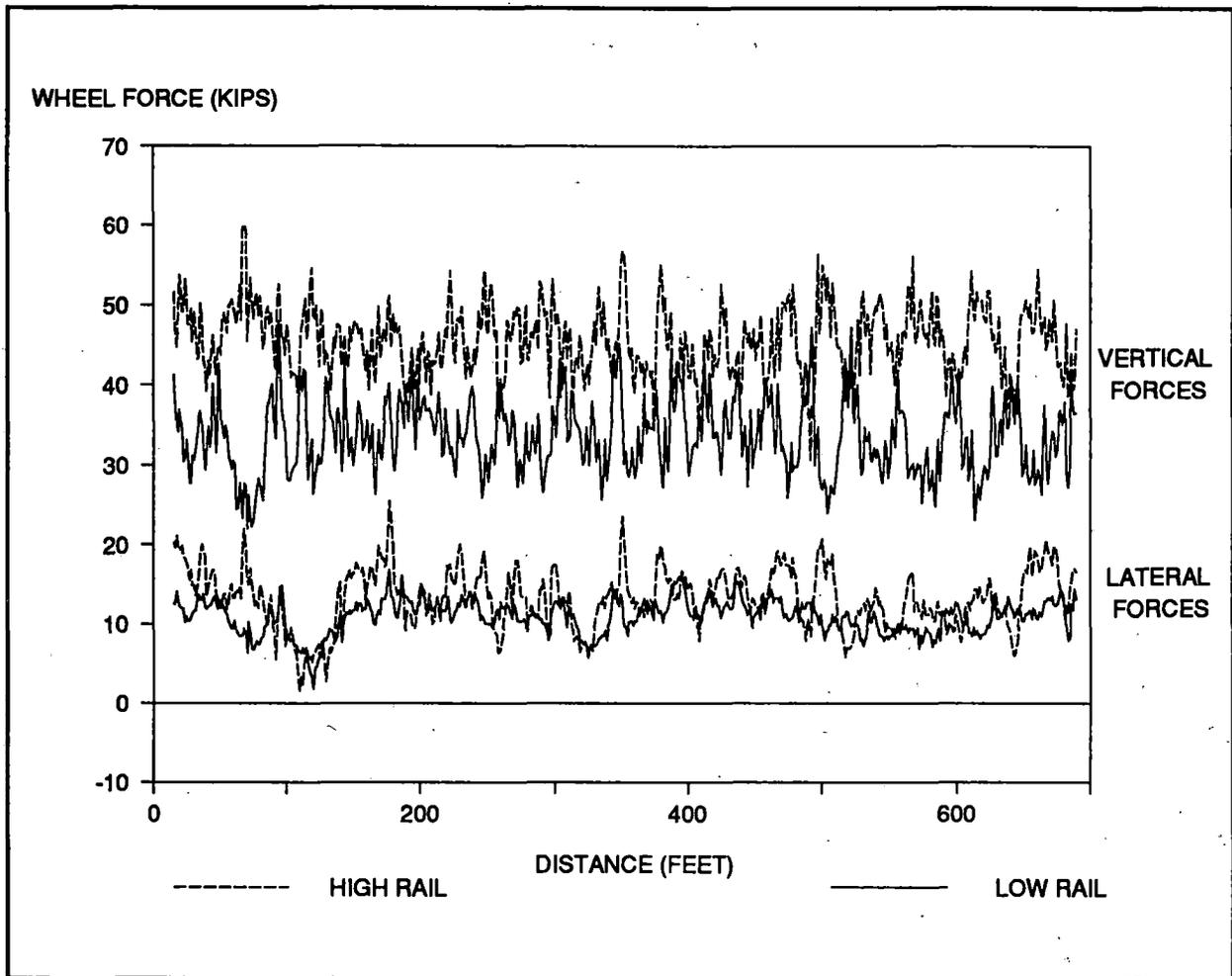
Figure 10. Time History of Lead-Axle Wheel Forces in Section 03

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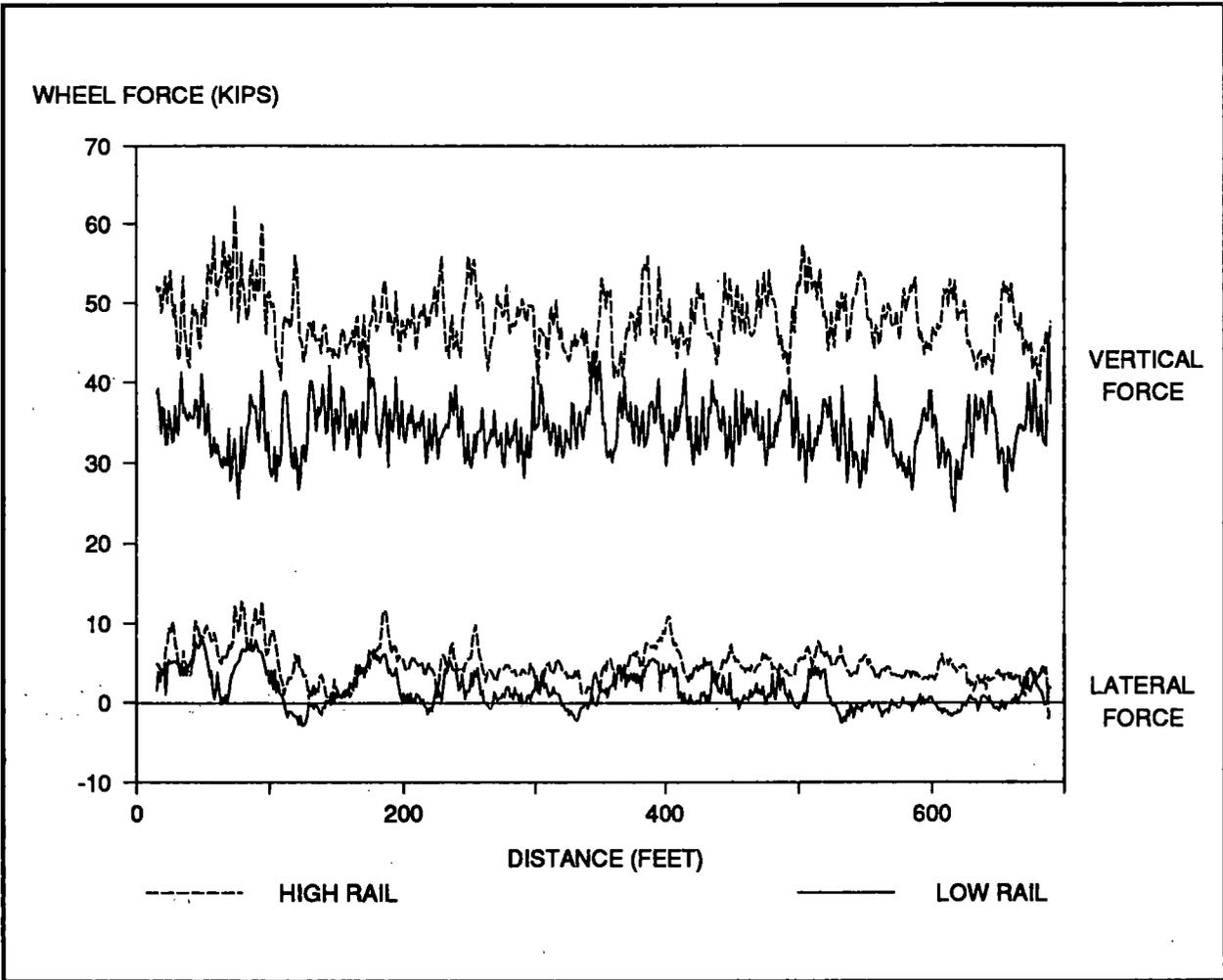
Figure 11. Time History of Trailing-Axle Wheel Forces in Section 03

The lead axle forces measured through a segment of tangent track (Section 29) are shown in Figure 12. Note that the vertical forces are nearly equal on each rail, as is expected for tangent track, and the lead axle lateral forces are small, as is also expected for tangent track.

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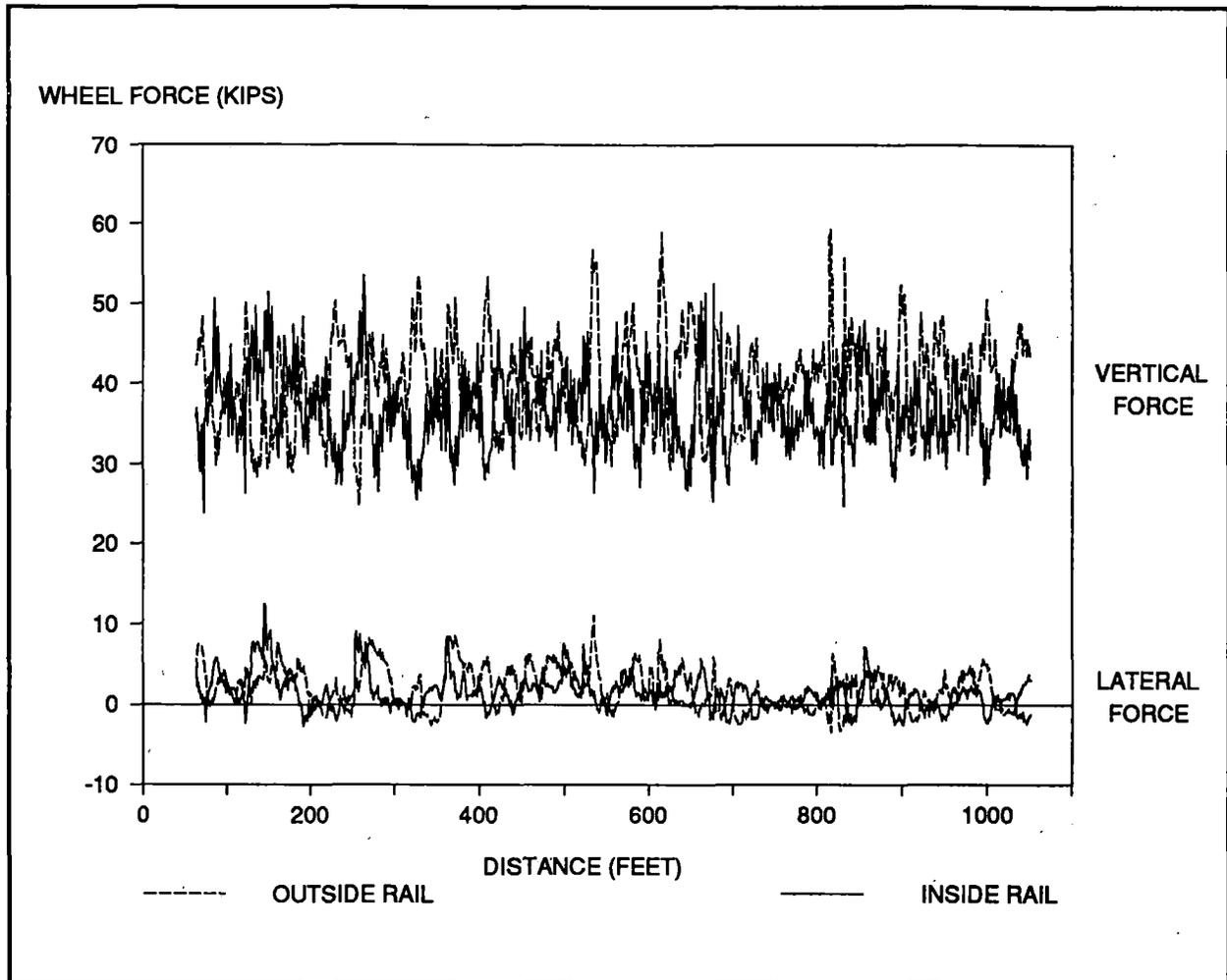
Figure 12. Time History of Lead-Axle Wheel Forces in Section 29

A summary of the average vertical forces, lateral forces, and L/V ratios for both Sections 03 and 29 is listed in Table 4. Given the fundamental differences between wayside and onboard measurements, these values would not necessarily agree with the wayside data presented earlier. The data from Section 03 does, however, exhibit the same general trends and similar force levels to those measured at the Section 03 wayside measurement site. In this way the instrumented wheel set data supports the wayside data.

Table 4. Average Section 03 Wheel Force Values

LEAD AXLE	LOW RAIL	HIGH RAIL
Vertical Force (kips)	33.6	45.6
Lateral Force (kips)	10.9	13.3
L/V Ratio	0.32	0.28
TRAIL AXLE		
Vertical Force (kips)	34.1	48.0
Lateral Force (kips)	1.6	4.7
L/V Ratio	0.04	0.09

Table 5. Average Section 29 Wheel Force Values

LEAD AXLE	INSIDE RAIL	OUTSIDE RAIL
Vertical Force (kips)	36.7	40.1
Lateral Force (kips)	1.4	2.1
L/V Ratio	0.03	0.04
TRAIL AXLE		
Vertical Force (kips)	39.7	41.6
Lateral Force (kips)	2.0	4.4
L/V Ratio	0.04	0.10

5.0 CONCLUSIONS

1. The average peak vertical rail forces measured in Section 03 increased between 26 percent and 27 percent in response to the 20 percent increase in the static vertical wheel loads. Average peak lateral forces in Section 03 increased between 19 percent and 21 percent in response to the static load increase.

2. Rail force data collected in Section 07 was more varied than that in Section 03, with average high rail vertical forces increasing 25 percent with vehicle type and average low rail vertical forces increasing 35 percent. Average lateral forces generated by the 39-ton cars were 13 percent and 28 percent higher on the high and low rails respectively than the average forces produced by the 33-ton axle load cars.

3. Increasing the static wheel load did not result in higher L/V ratios at either measurement location.

4. The average high rail vertical forces measured in Section 07 were about 24 percent higher for both vehicle types than the vertical forces measured in Section 03. The presence of a corrugated rail at the Section 07 location is felt to have contributed to the vertical force increase.

5. The forces measured using instrumented wheel sets generally agreed with those measured using instrumented rail circuits.

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3. Hannafious, Jon. "Rail Performance," *Preprints, Workshop on Heavy Axle Loads*, Pueblo, Colorado, October 14-17, 1990, pp. 10-1 to 10-13.

4. Laine, K. J. and N. G. Wilson. "Effect of Track Lubrication on Gage Spreading Forces and Deflections," R-712, Association of American Railroads, Transportation Test Center, Pueblo, Colorado, August 1989.

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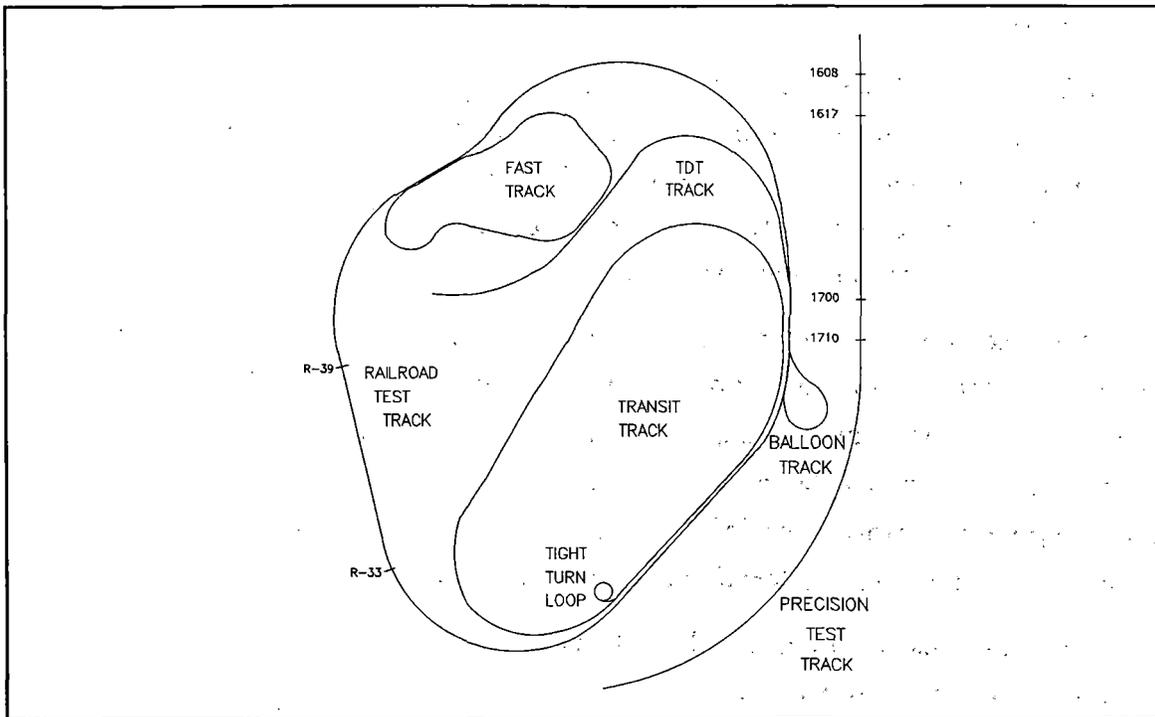
**Figure 1. Test Tracks at High Speed Ground Test Center, Pueblo, CO, Showing
General Location of FAST**

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.
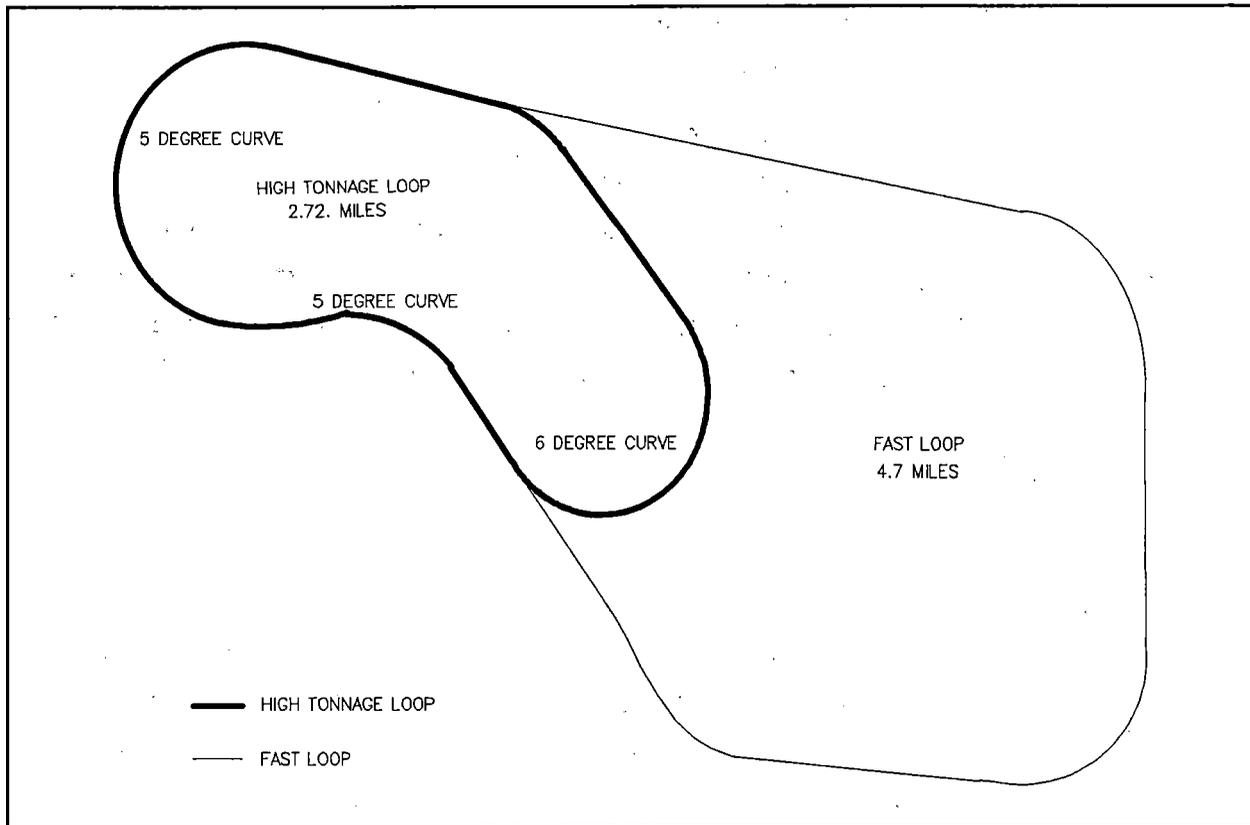
Figure 2. High Tonnage Loop

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.
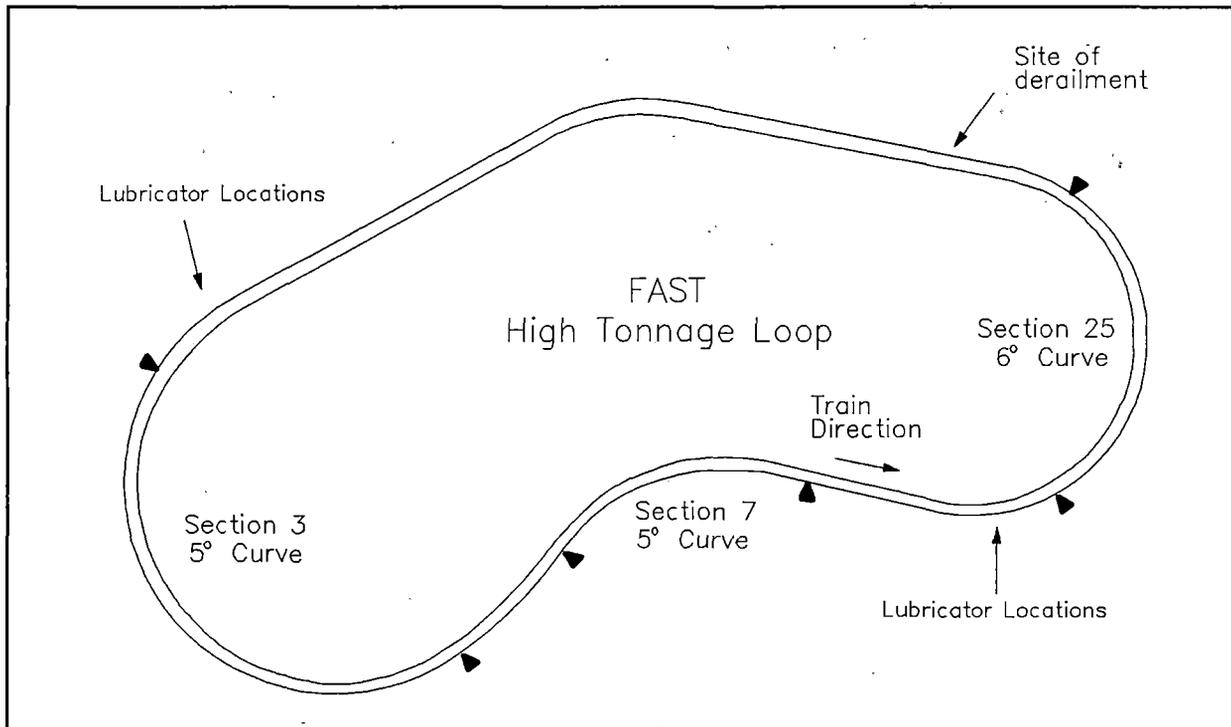

Figure 3. Lubricator Locations on the High Tonnage Loop

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.
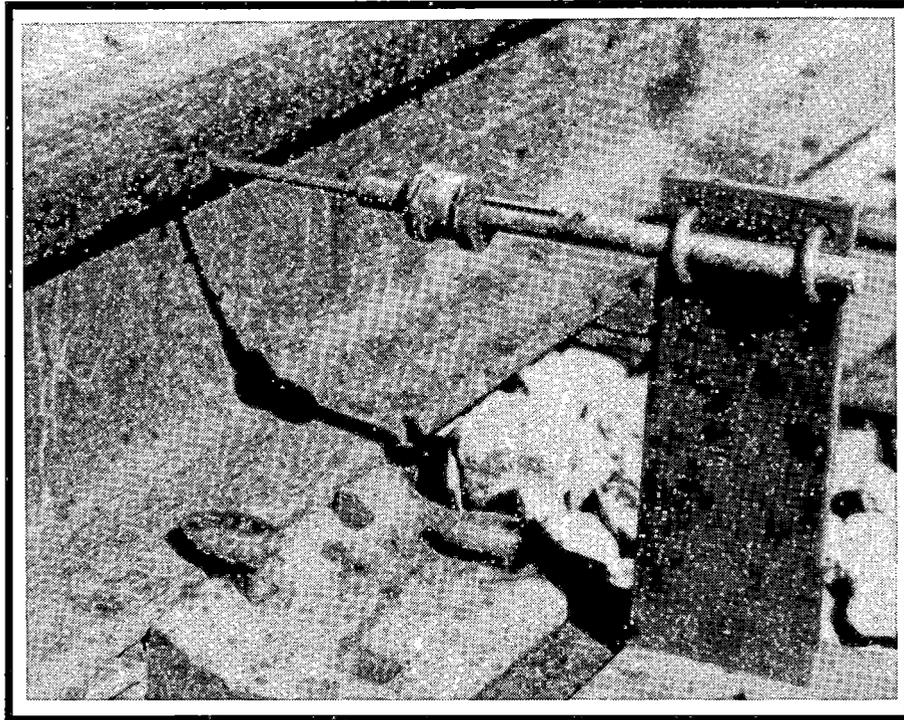
Figure 4. Tell Tale Installed on the HTL

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.
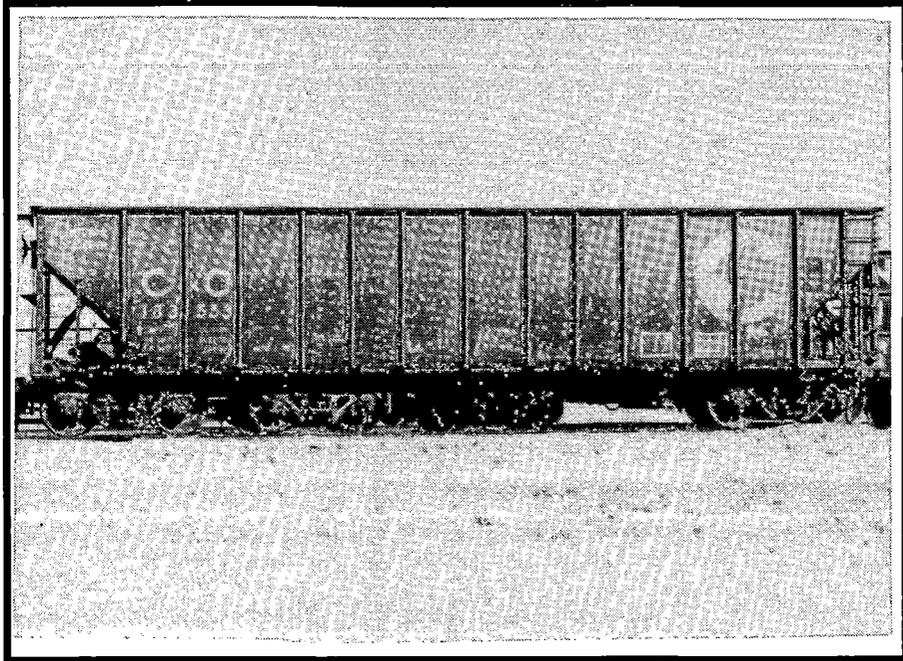
Figure 5. Typical 100-ton Capacity Car

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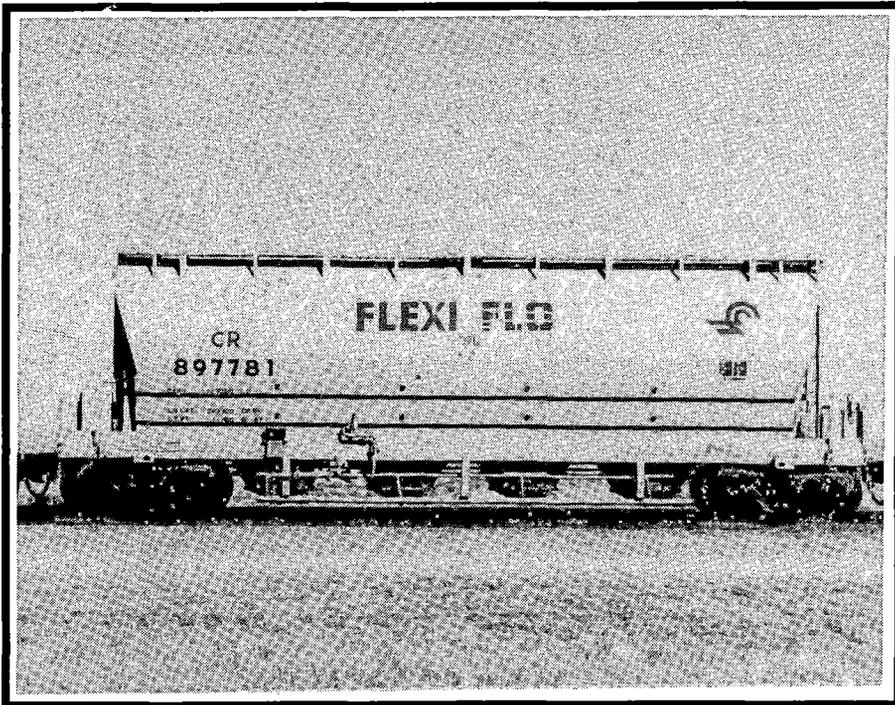
Figure 6b. Typical 125-ton Capacity Covered Hopper Car

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

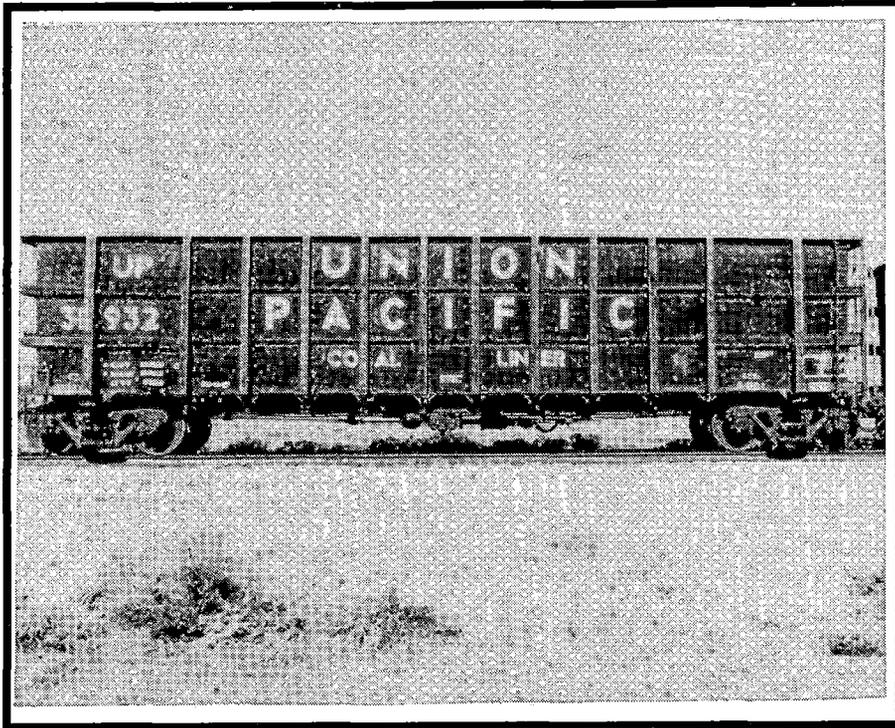| COMMON NAME	ACTUAL CONFIGURATION
100-ton car	100 tons of lading 31.5 tons of empty car weight 131.5 tons on the rail 263,000 lbs on the rail 33,000 lbs per wheel (33 kips) 36" diameter wheel (33-ton axle load)
125-ton car	124.5 tons of lading 33 tons of empty car weight 157.5 tons on the rail 315,000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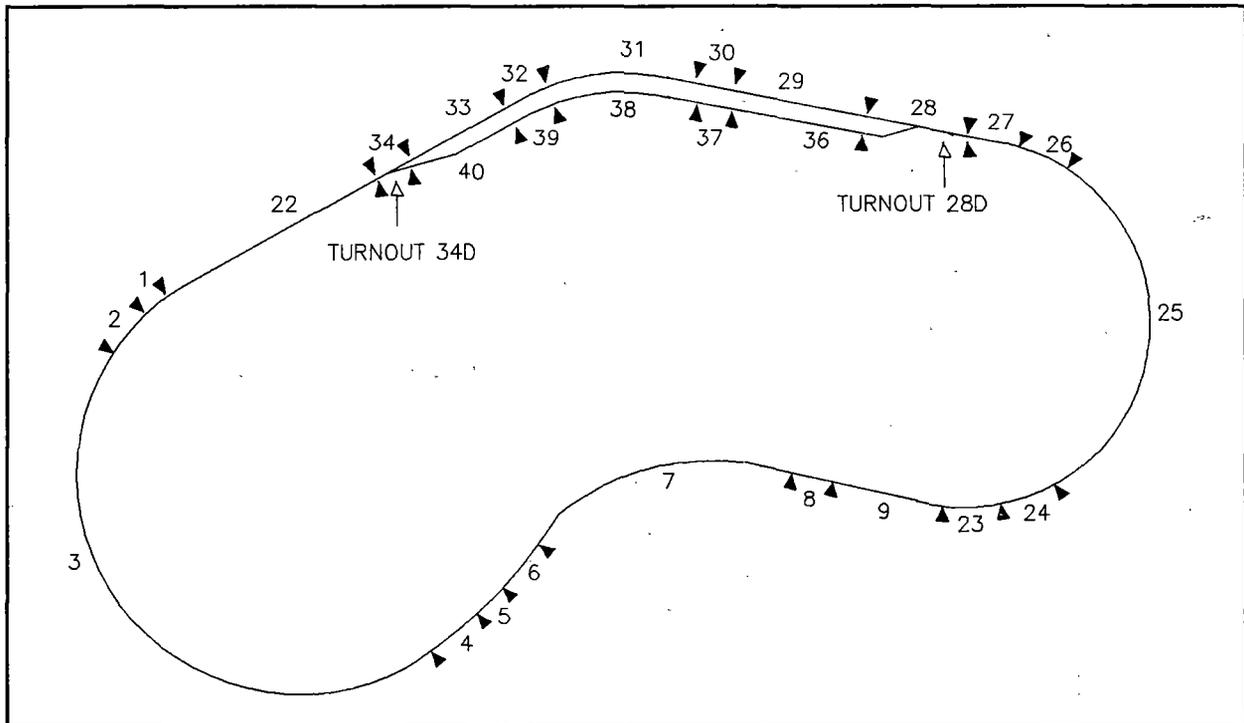

Figure 7. Map of HTL with By-Pass Track Added at Start of HAL Operations

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.
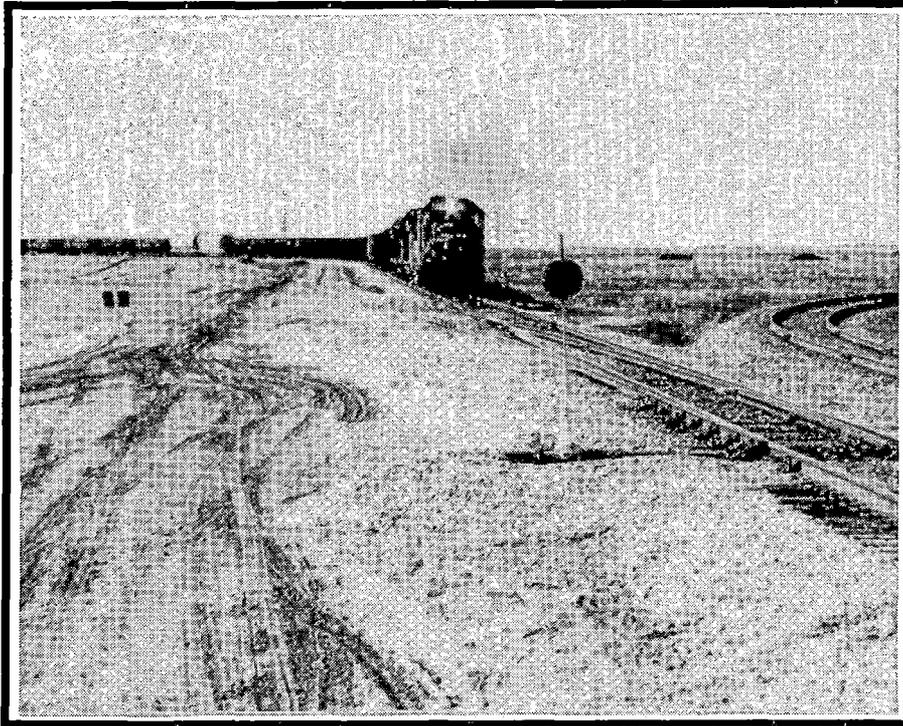
Figure 8. Typical HAL Train in Operation

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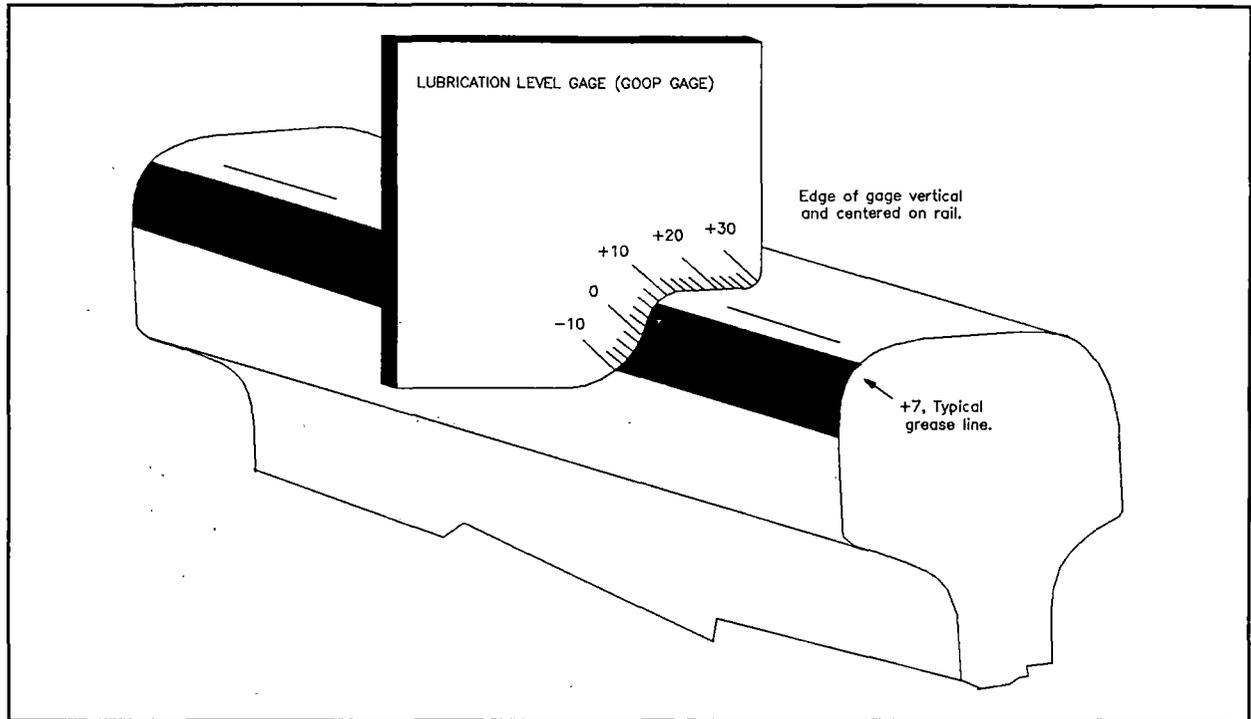
Figure 9. TTC's Lubricant Level Gage (Goop Gage)

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.
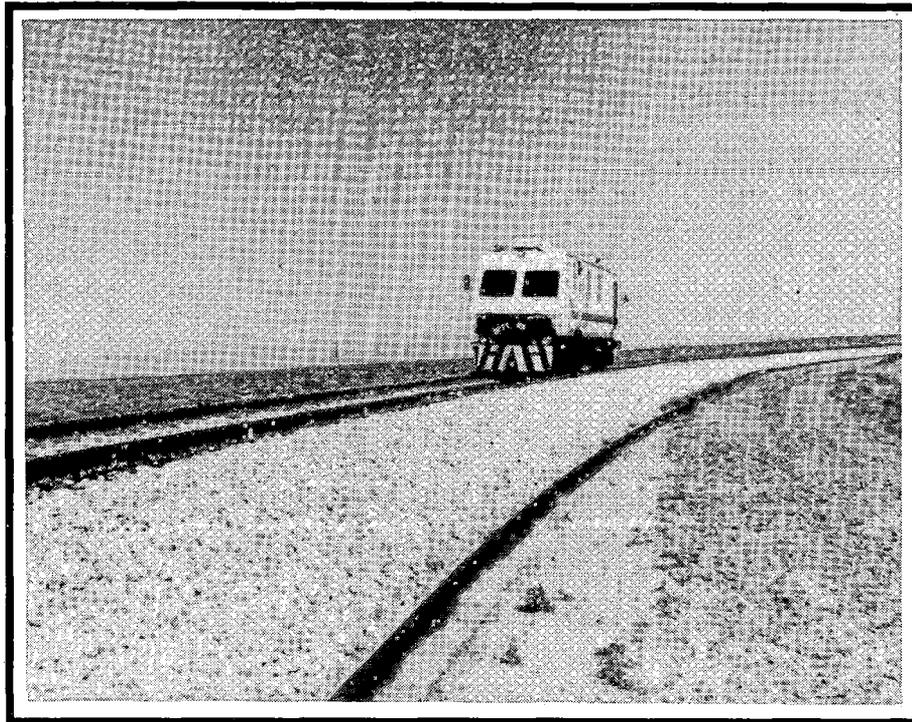
Figure 10. EM80 Track Geometry Car

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.
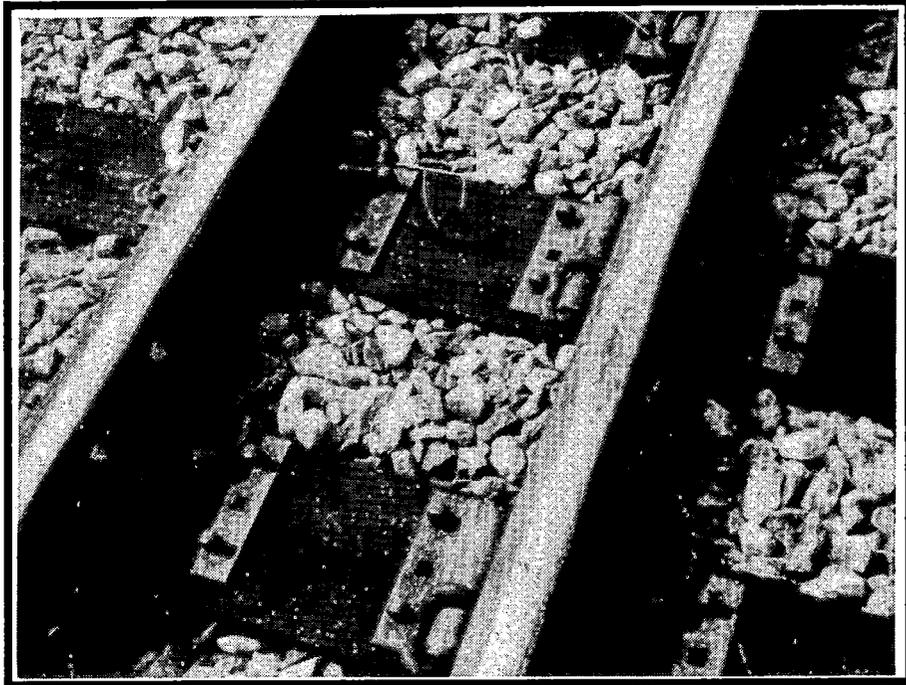
Figure 11. Typical Welded Rail Joint Batter
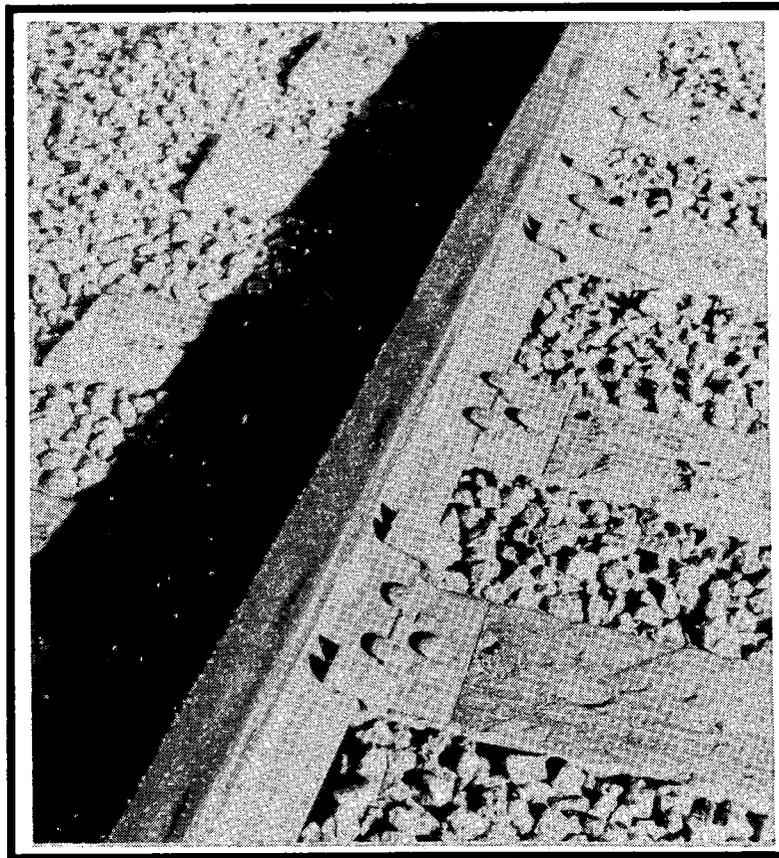
Figure 12. Typical Corrugations

Figure 13. Typical Broken Field Weld
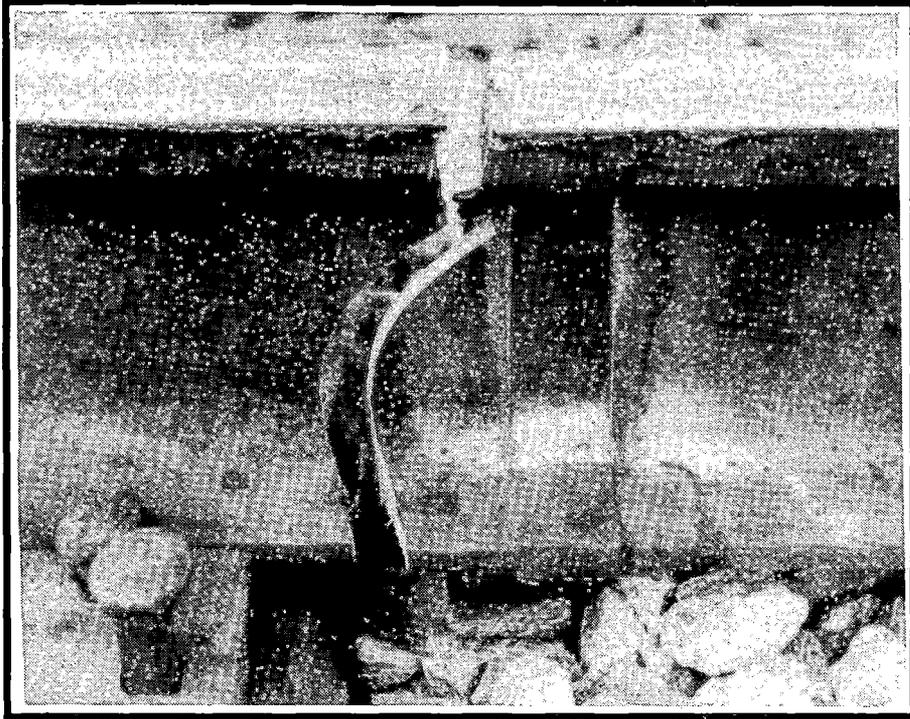
Under the HAL train operation, turnouts were second to field weld failures in the area of increased track maintenance. As with conventional field weld material, standard rail and frog components exhibited the shortest life and highest amount of maintenance and repair (Figure 14). Overall, turnouts required a significant increase in spot maintenance, grinding, and buildup requirements.
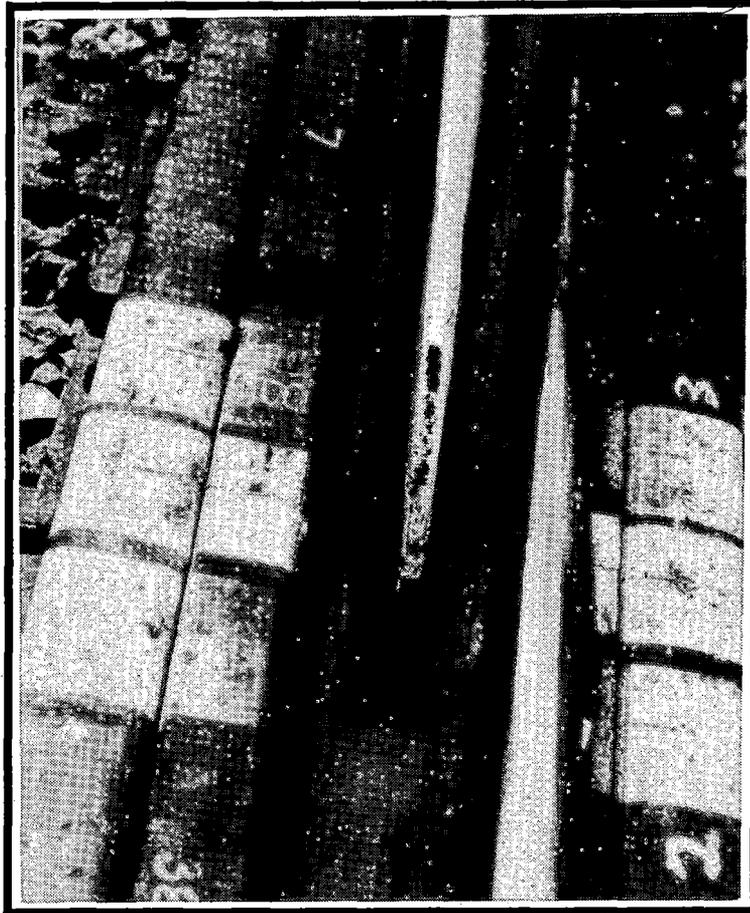
Figure 14. Typical Worn Frog Components

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.
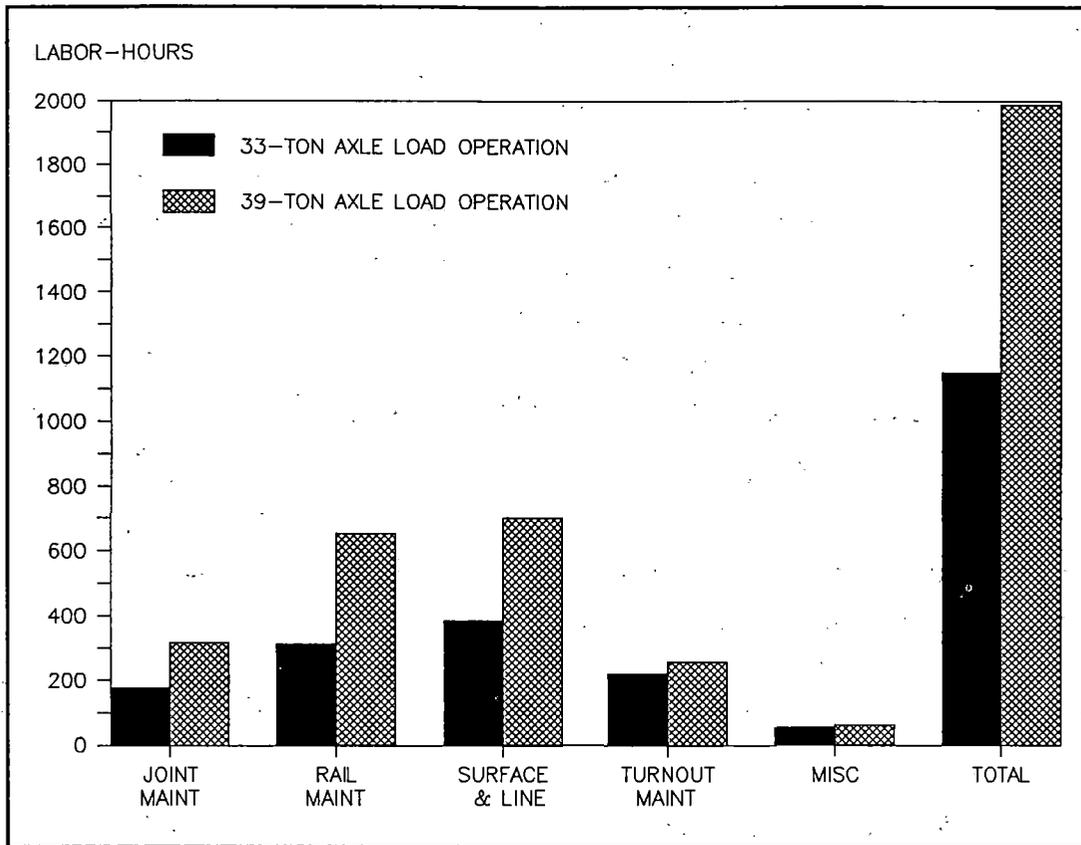
Figure 15. Breakdown of Track Maintenance Effort

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.
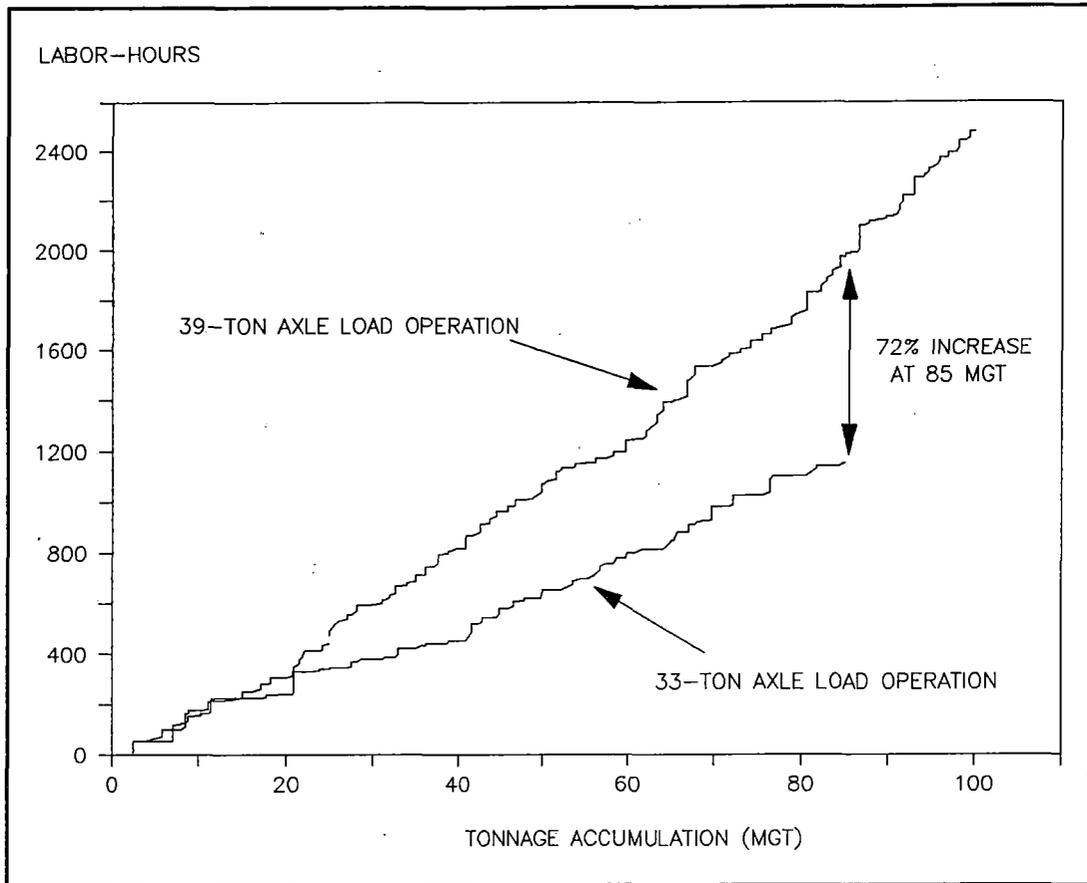
Figure 16. Track Maintenance Effort as a Function of Tonnage

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 rail-bound 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.
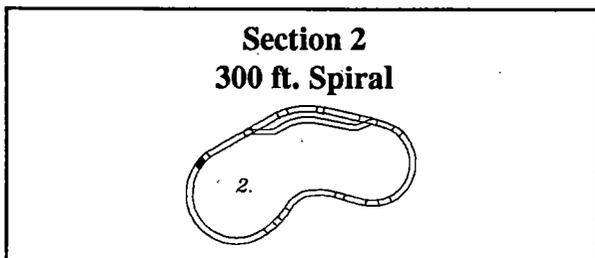
Metallurgical Evaluation

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

1.
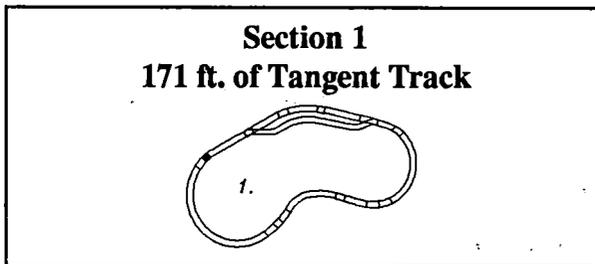
Transition zone/available for testing. Location of hot bearing detector.

Section 2
300 ft. Spiral

2.

Transition zone/available for testing.

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

3.
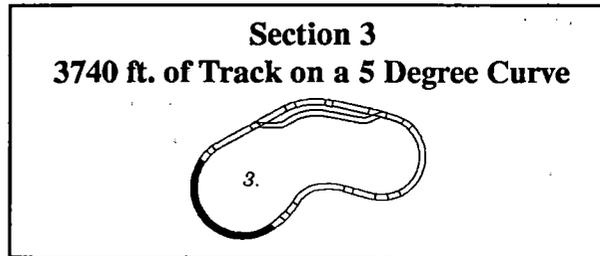
Location of Ballast, Rail Performance and Tie and Fastener Experiments.

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

4.
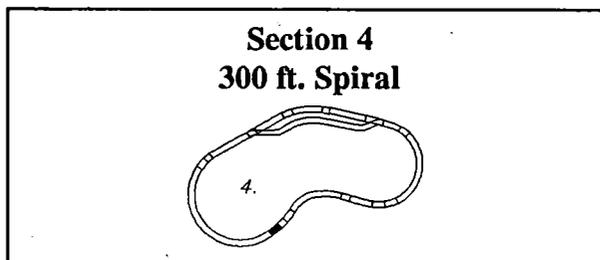
Transition zone/available for testing.

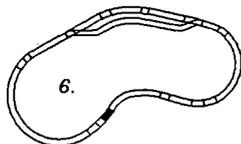**Section 5**
224 ft. of Tangent Track

5.
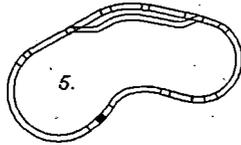
Location of Subgrade Experiment and Frog Casting Performance Test.

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.

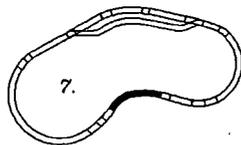Location of hot bearing and acoustic bearing detector.

Section 6
300 ft. Spiral

6.

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

7.

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
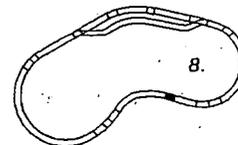
8.

Location of Ballast Resistance Characterization Experiment.

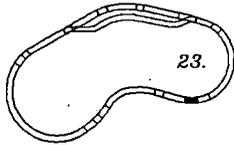Measurements include lateral ballast resistance as measured with the single tie push test.

Section 9
313 ft. of Tangent Track

9.
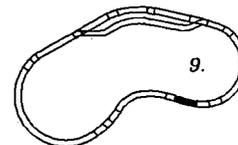
Road crossing and #10 turnout.

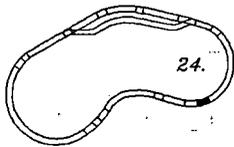Proprietary test of uncased 12 inch and 36 inch pipes buried under railroad track.

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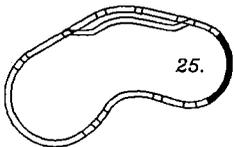
Frog Casting Performance Test.

Wayside rail lubricator.

Section 24
300 Ft. Spiral

Transition zone/available for testing.

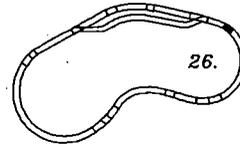## Section 25
2692 ft. of Track on a 6 Degree Curve

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.
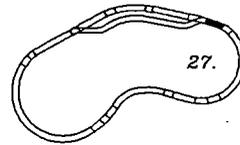
Section 26
300 ft. Spiral

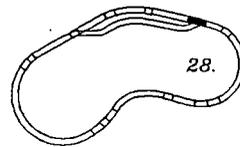Location of Tie and Fastener Experiment.

Measurements include static gage widening.

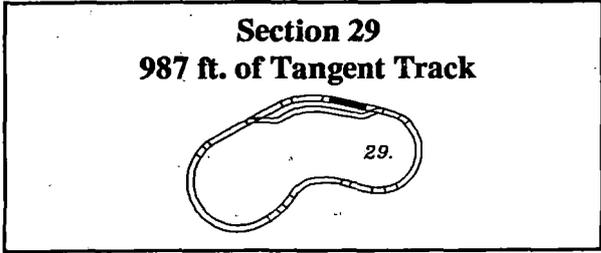## Section 27
332 ft. of Tangent Track

Location of Frog Casting Performance test.

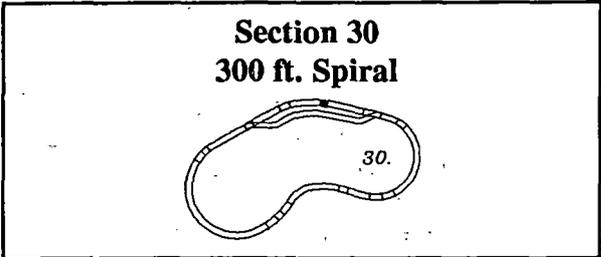## Section 28
#20 Left Hand Turnout

Location of Turnout Experiment.

Measurements include rail/wheel loads, dynamic rail deflections, lateral and vertical rail stiffness and track geometry.
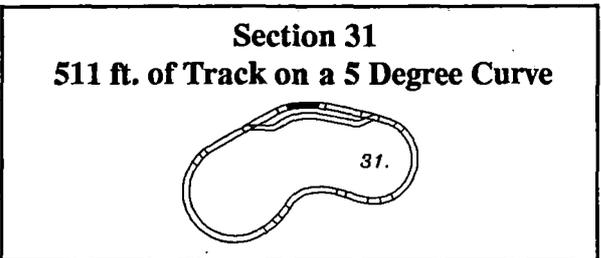
Section 29
987 ft. of Tangent Track

Location of Track Irregularity Experiment

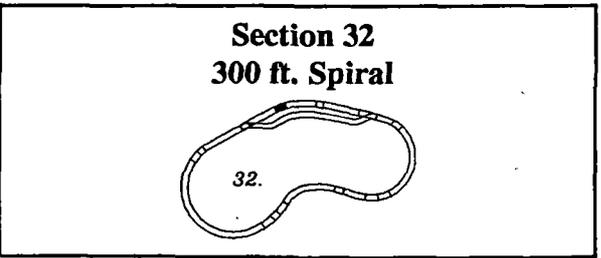Measurements include rail/wheel loads, dynamic rail deflections, vertical track stiffness and track geometry.

Section 30
300 ft. Spiral

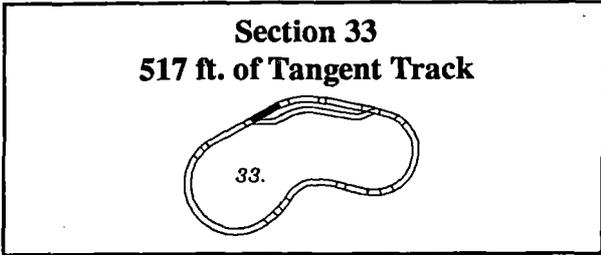Transition zone/available for testing.

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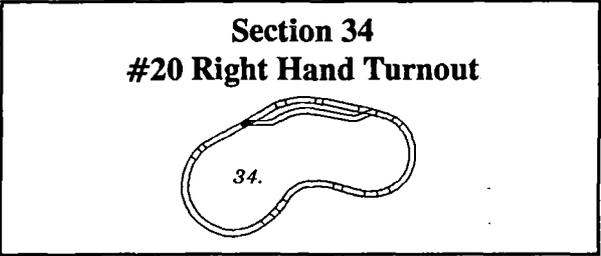
Location of Ballast Resistance Characterization Experiment and Frog Casting Performance Test.

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.
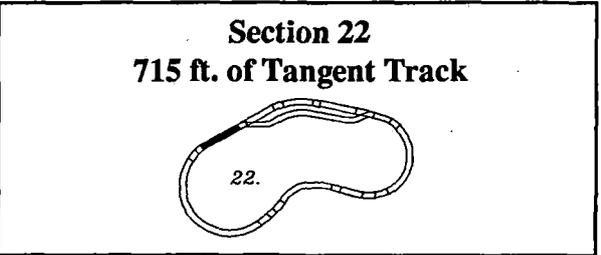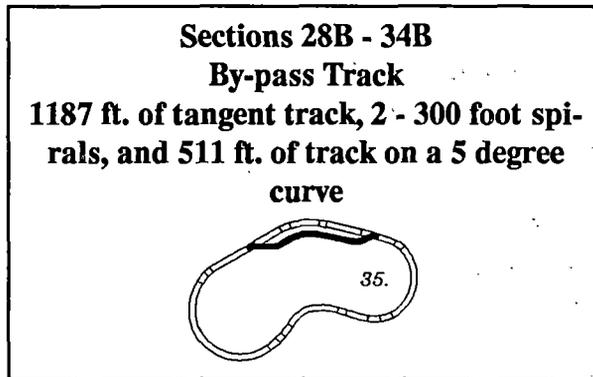
Section 22
715 ft. of Tangent Track

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

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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.

REPORT BRIEF

FAST/HAL TRACK LOADS
EVALUATION

R-791

October 1991

The FAST/HAL Track Loads Evaluation was conducted to quantify vertical and lateral forces at the Facility for Accelerated Service Testing, Transportation Test Center, Pueblo, Colorado, under 33- and 39-ton axle load cars. Vertical rail forces beneath the 39-ton axle load cars were found to be 25 percent to 35 percent higher than those beneath the 33-ton axle load cars. Lead axle lateral rail forces were from 13 percent to 28 percent higher under the 39-ton axle load cars. There were no significant differences in lateral to vertical force (L/V) ratios. The lateral forces and L/V ratios for both the 33- and 39-ton axle load cars were found to be dependant upon lubrication conditions. Corrugated rail was found to induce higher vertical forces than rail with no visible surface defects.

The vertical and lateral force measurements were taken using instrumented rail circuits at two separate locations in 5-degree curves. The loads were measured beneath a train of 14 each of 33- and 39-ton axle load cars which was operated at 40 mph to 42 mph. In addition, a pair of instru-

mented wheel sets was installed in a 39-ton axle load car to measure vertical and lateral forces. The measurements taken with the instrumented wheel sets generally supported those taken at the wayside locations.

Copies of the AAR Report: "FAST/HAL Track Loads Evaluation," are available from the Document Distribution Center, Chicago Technical Center, 3140 South Federal Street, Chicago, Illinois 60616. The AAR report number is R-791; 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 October, 1991. A report list is available upon request.

FAST/HAL Track Loads Evaluation, 1991
Association of American Railroads, David M
Read, Duane E Otter

ASSOCIATION
OF AMERICAN
RAILROADS

U.S. Department
of Transportation

**Federal Railroad
Administration**