

**FAST/HAL
MECHANICAL COMPONENTS
PERFORMANCE TEST**

**AAR REPORT R-787
FRA/ORD-91/09**



ASSOCIATION
OF AMERICAN
RAILROADS



U.S. Department
of Transportation
**Federal Railroad
Administration**

***Facility for Accelerated Service Testing
Heavy Axle Load Program***

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MECHANICAL COMPONENTS
PERFORMANCE TEST**

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13. Abstract <p>The Association of American Railroads and the Federal Railroad Administration conducted a research program to investigate the implications of operating Heavy Axle Load (HAL) freight cars using a controlled consist of locomotives and fully loaded HAL freight cars equipped with conventional three-piece trucks at the Facility for Accelerated Service Testing, Transportation Test Center, Pueblo, Colorado. During the 160 MGT program, the performance of the car and locomotive mechanical components was monitored in the Mechanical Component Performance Experiment. A wheel performance test was conducted as a part of the Mechanical Component Performance Experiment to generate data on the wear behavior of heat treated wheels operating in the HAL environment.</p> <p>The Wheel Performance Test was designed to monitor wear behavior for new AAR Class C, two-wear cast steel wheels operating under 33- and 39-ton axle load cars equipped with Barber S-2 three-piece trucks and loaded to a rail weight of 157.5 tons and 132.0 tons, respectively, under dry and lubricated rail conditions. Comparative data obtained during the experiment included:</p> <ul style="list-style-type: none">• Flange and rim wear as a function of accumulated mileage for each car type.• Wheel profile variations as a function of wheel position for each car type. <p>The tests revealed that, on a car mileage basis, there was no statistically significant difference in the flange or rim wear data obtained for the two car types.</p> <p>During the course of the program, corrugations were observed on the wheels of both 33- and 39-ton axle load cars. Since corrugated wheels have not been reported as a problem occurring on 33-ton axle load cars currently operating in revenue service, it appears that the corrugations occurred due to the nature of the HAL consist operation and the design of the High Tonnage Loop and are not associated with the increased axle load condition.</p>		
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EXECUTIVE SUMMARY

A research program to investigate the implications of operating Heavy Axle Load (HAL) freight cars was conducted by the Association of American Railroads (AAR), in conjunction with the Federal Railroad Administration, at the Transportation Test Center, Pueblo, Colorado. During the program, the performance of car and locomotive mechanical components was monitored in the Mechanical Component Performance Experiment. A Wheel Performance Test was conducted as a part of this experiment to generate data on the wear behavior of heat treated wheels operating in the HAL environment.

On a car mileage basis, there was no statistically significant difference in the flange or rim wear data obtained for the two car types. It should also be noted that due to differences in wheel circumference, the wheels on the 39-ton axle load cars completed approximately 5 percent fewer revolutions per mile than those on the 33-ton axle load cars. Significant plastic deformation of the wheel tread occurred on the wheels of both car types during the test. It is suspected that the tread deformation for both car types occurred partially a result of the nature of the HAL train operation and the design of the HTL.

The HAL consist completed 160 million gross tons (MGT) of simulated revenue service operation during the program. The program was divided into two phases. The first phase consisted of 15 MGT of operation under non-lubricated (dry) rail conditions, while the second phase consisted of 145 MGT of operation with lubrication applied to the outside rail of the HTL by means of a wayside lubricator.

The Wheel Performance Test cars completed 29,000 miles of operation during the program. Of the 29,000 miles, 3,500 were completed under dry rail conditions. Due to the design of HTL, with nearly 78 percent of the track composed of curves and spirals, accelerated flange wear rates are achieved, and approximately 90 percent of the available flange material was used up on the test wheels. The rate of rim wear achieved on the HTL is not significantly accelerated over those obtained in revenue service, and only approximately 10 percent of the available rim material was used up on the test wheels.

During the program the wheels on some of the cars developed corrugations. Metallurgical evaluation of corrugated wheels removed from two HAL cars revealed excessive metal flow and plastic deformation on the corrugated wheels with cracks originating at the surface and propagating in the direction of the deformation. The mate wheels showed significantly less metal flow and no cracking. There was no evidence of thermal input due to wheel sliding or prolonged tread braking on any of the wheels.

The new Class C wheels installed in the 33- and 39-ton axle load cars used in the Wheel Performance Test also developed corrugations over the course of the program. The corrugations were similar in appearance and severity for both car types.

Since corrugations were observed on the wheels of both 33- and 39-ton axle load cars during the course of the HAL program, and since corrugated wheels have not been reported as a problem occurring on 33-ton axle load cars currently operating in revenue service, it appears that the corrugations occurred due to the nature of the HAL consist operation and the design of the HTL. At this time, it does not appear that the corrugations are associated with the increased axle load condition. It should also be noted that most of the wheels developed corrugations during the initial stages of the lubricated phase of the program. The number of corrugated wheels decreased as the program continued.

Based on the results of the Wheel Performance Test, the following action will be pursued during the next phase of operation of the HAL program:

- Continue the Mechanical Component Performance Experiment during the next phase of the HAL program in which the consist will be operated in both the clockwise and counterclockwise directions on the HTL.
- Conduct a wheel performance test using three fully loaded 39-ton axle load cars and three fully loaded 33-ton axle load cars equipped with AAR Class C, two-wear cast steel wheels machined to an AAR 1B pro-

file to document wheel performance under bidirectional operating conditions including the occurrence of plastic deformation on the tread of the wheels.

- Install special air brake control equipment on a selected number of cars so the effects of cyclic tread braking on wheel performance can be investigated.

The cars used in the Wheel Performance Test included two 39-ton axle load open top hopper cars and three 33-ton axle load open top hopper cars. All of the cars were equipped with Barber S-2 three-piece trucks. An expanded shale material was used to load the cars to a gross rail load of 157.5 tons and 132.0 tons, respectively.

A wheel snap gage was used to determine changes in the flange and rim thickness of the test wheels at one location on each wheel. The gage uses the same reference point on the wheel surface as the AAR Standard Steel Wheel Gage and employs three dial indicators that have a resolution of 0.001 inch, providing an overall system accuracy of 0.005 inch. The Snap Gage measurements were made at the completion of approximately every 1,200 miles of operation.

A longitudinal wheel profilometer was used to measure the longitudinal profile of each of the wheel sets at the completion of the on-track testing. The profilometer measures instantaneous radial runout of each wheel while simulating rail contact by using a special shoe that diminishes the effects of shells on the wheel tread surface. A British Rail profilometer was used to document the lateral profile at one location on the test wheels at the completion of the on-track tests.

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1.0 INTRODUCTION

A research program to investigate the implications of operating Heavy Axle Load (HAL) freight cars using a controlled consist of locomotives and fully loaded freight cars equipped with conventional three-piece trucks was conducted by the Association of American Railroads (AAR) in conjunction with the Federal Railroad Administration (FRA). The cars were operated for 160 million gross tons (MGT) of simulated revenue service operation on the High Tonnage Loop (HTL) of the Facility for Accelerated Service Testing (FAST), Transportation Test Center (TTC), Pueblo, Colorado.

The program was divided into two phases. The first phase consisted of 15 MGT of operation under non-lubricated (dry) rail conditions, while the second phase consisted of 145 MGT of operation with lubrication applied to the outside rail of the HTL by means of a wayside lubricator. During the 160 MGT program, the performance of the car and locomotive mechanical components was monitored in the Mechanical Component Performance Experiment.

2.0 OBJECTIVE

A Wheel Performance Test was conducted as a part of the Mechanical Component Performance Experiment to generate data on the wear behavior of heat treated wheels operating in the HAL environment.

3.0 PROCEDURES

The Wheel Performance Test was designed to monitor wear behavior for AAR Class C two wear cast steel wheels operating under loaded open top hopper cars in dry and lubricated rail conditions. A comparison of wheel performance for fully loaded 33- and 39-ton axle load cars was generated by the experiment. Comparative data obtained during the experiment included:

- Flange and rim wear as a function of accumulated mileage for each car type
- Wheel profile variations as a function of wheel position for each car type
- Surface defect initiation and growth for each car type

3.1 WHEEL IRREGULARITIES

The scope of the Mechanical Component Performance Experiment included monitoring the performance of the components on all of the freight cars used in the HAL consist. At the completion of approximately every 300 laps on the HTL, the entire HAL consist received a complete maintenance inspection.

During a maintenance inspection performed in February 1989, Car 330, one of the 39-ton axle load open top hopper cars, was removed from service because of severe wheel tread shelling. The car was equipped with AAR Class B wheels that had completed approximately 3,950 miles of dry operation and 660 miles of lubricated operation on the HTL in addition to an unknown amount of revenue service mileage. Examination of the shelled wheel tread surfaces revealed a corrugated wear pattern made up of alternating crests and troughs spaced approximately 7 inches apart having a circumferential length of 5 to 6 inches. The shelling occurred near the crests of the corrugations.

Subsequent inspection of the HAL consist revealed that approximately 10 percent of the wheels in the fleet showed evidence of corrugations occurring on the wheel tread. One wheel set was removed from Car 330 and sent to the AAR's Chicago Technical Center (CTC) for metallurgical evaluation. A wheel set removed from Car 355 (another 39-ton axle load open top hopper car equipped with Class B wheels manufactured by Griffin Wheel Company) showed evidence of corrugations, but no shelling. It was sent to Griffin's Laboratories in Chicago, Illinois, for evaluation.

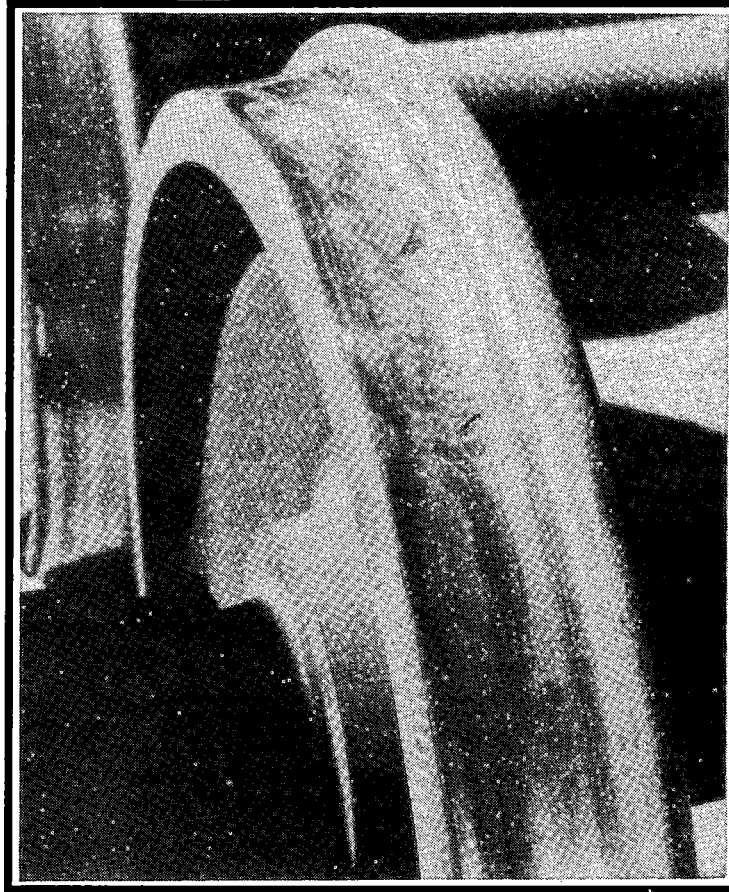


Figure 1. Corrugated and Shelled Class B Wheel from Car 330

In order to investigate the initiation and growth rate of the corrugations and shelling, all wheel sets in Car 330 were replaced with new AAR Class C two-wear cast steel wheels machined to an AAR 1:20 profile. The condition of the wheels was monitored at regular intervals for the remainder of the HAL program. The wheels of all cars in the HAL consist were inspected approximately every 2,500 miles of operation to monitor the number of corrugated and shelled wheels.

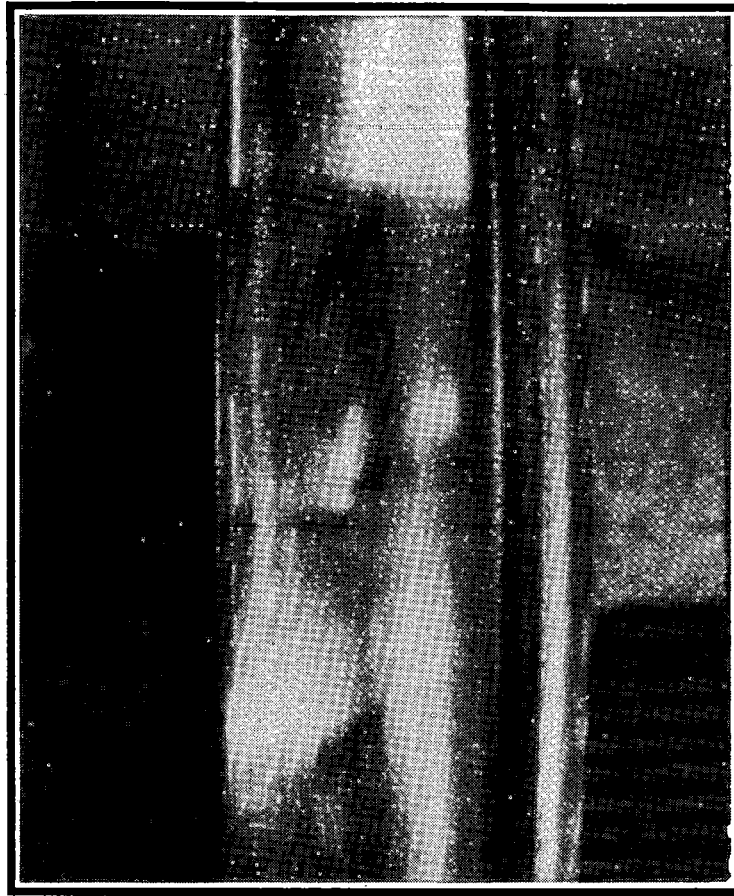


Figure 2. Corrugated Class B Wheel from Car 335

3.2 WHEEL SIZE AND PROFILE

The freight cars used in the HAL program were initially equipped with wheel sets having service worn profiles. As wheel sets were removed from service due to wear, they were replaced with wheel sets machined to an AAR 1:20 profile.

Prior to the start of the Wheel Performance Test, wheel sets equipped with new AAR Class C, two-wear cast wheels, machined to an AAR narrow flange 1:20 profile, were installed in axle positions 1 and 3 (test wheels) of the test cars while wheels with a service worn profile were left in axle positions 2 and 4 (non-test wheels). Figure 3 illustrates the location of the test wheel sets.

The 33-ton axle load cars used in the experiment were equipped with 36-inch-diameter wheels having a nominal circumference of approximately 113 inches. Thus, the 33-ton axle load wheels completed approximately 560 revolutions per mile of operation. The 39-ton axle load cars were equipped with 38-inch-diameter wheels having a nominal circumference of approximately 119.5 inches. The 39-ton axle load wheels completed approximately 531 revolutions per mile of operation or approximately 5 percent fewer revolutions per mile of operation.

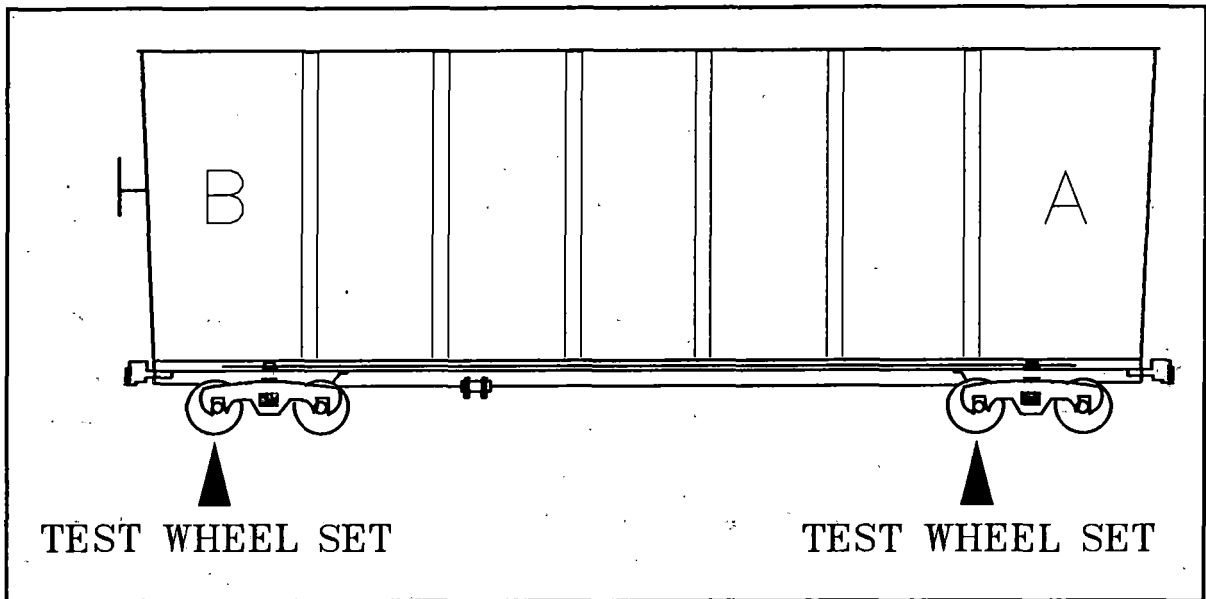


Figure 3. Wheel Performance Test Wheel Set Locations

3.3 TEST CONSIST

The cars used in the Wheel Performance Test included two 39-ton axle load open top hopper cars and three 33-ton axle load open top hopper cars. All of the cars were equipped with Barber S-2 three-piece trucks. An expanded shale material was used to load the cars to a gross rail load of 157.5 tons and 132.0 tons, respectively.

3.3.1 Frame Braced Truck Evaluation

Under the original planning for the Wheel Performance Test, three 39-ton axle load open top hopper cars equipped with National C-1 Wedgelock trucks were modified with frame bracing provided by the Urban Transportation Development Division of

Lavalin (UTDC). The cars equipped with frame-braced trucks, and three fully loaded 39-ton axle load open top hopper cars equipped with standard National C-1 Wedgelock trucks, were to be operated with the other Wheel Performance Test cars for a minimum of 10,000 miles under dry rail conditions. The 10,000 miles of operation included 5,000 miles of operation (15 MGT) with the entire HAL consist, and 5,000 miles of operation in a mini-consist composed of one locomotive and the cars used in the Wheel Performance Test. Due to budgetary considerations within the HAL program, the operation of the mini-consist was eliminated from the Wheel Performance Test leaving only 15 MGT of dry rail operation.

By the completion of the 15 MGT phase of the HAL program, the cars used in the Wheel Performance Test had completed 3,500 miles of operation under dry rail conditions. A summary of the wheel wear data collected for the cars equipped with standard and frame braced trucks was provided to UTDC for review.

Upon review of the test data, UTDC requested that the cars equipped with frame bracing be dropped from the Wheel Performance Test, citing the limited amount of dry rail operation, and the use of lubrication on the rails of the HTL during the next 145 MGT phase of the HAL program. An Engineering Change Form was submitted by the AAR to the FRA requesting that the 39-ton axle load cars equipped with conventional and frame braced National C-1 Wedgelock trucks be dropped from the Wheel Performance Test effective January 1, 1989. The request was approved by the FRA and the 39-ton axle load cars equipped with conventional and frame braced National C-1 Wedgelock trucks were eliminated from the Wheel Performance Test.

3.4 CONSIST OPERATION

The cars used in the Wheel Performance Test were operated in a block as part of the HAL consist. The HTL, a 2.72 mile loop with one 6-degree curve and three 5-degree curves with connecting tangent sections, was used for mileage accumulation during the test. The HAL consist was operated primarily in the counterclockwise direction around the loop. At the completion of every 3 MGT of operation (approximately 800 miles), the HAL consist, including the test cars, was turned end-for-end. Figure 4 is an illustration of the HTL showing the curves, the location of the wayside lubricator, and the direction of train operation.

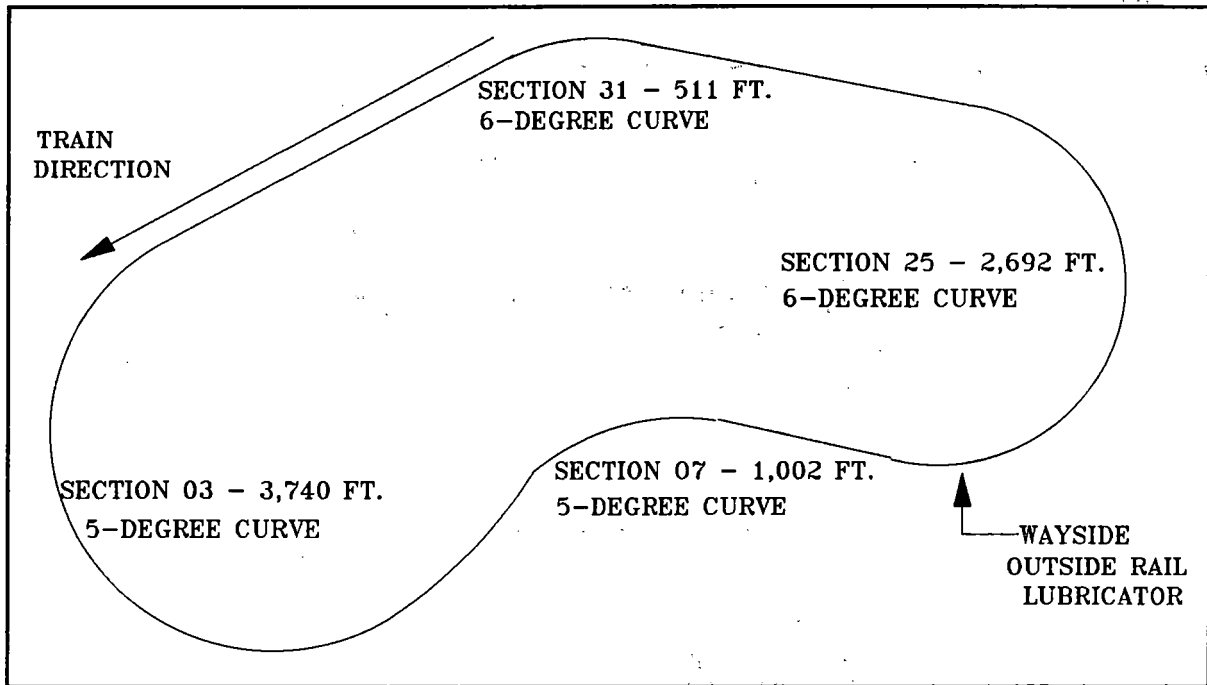


Figure 4. High Tonnage Loop.

As illustrated in Figure 5 when the B-end of the cars was the leading end, the test wheel sets operated in the leading axle position of each truck. In this mode of operation the wheels on the right side of the cars operated on the inside rail of the HTL while those on the left side operated on the outside rail of the HTL.

When the cars were turned end-for-end, the A-end of the cars became the leading end and the test wheel sets operated in the trailing position of each truck. In this mode of operation the wheels located on the right side of the cars operated on the outside rail of the HTL while those on the left side operated on the inside rail of the HTL.

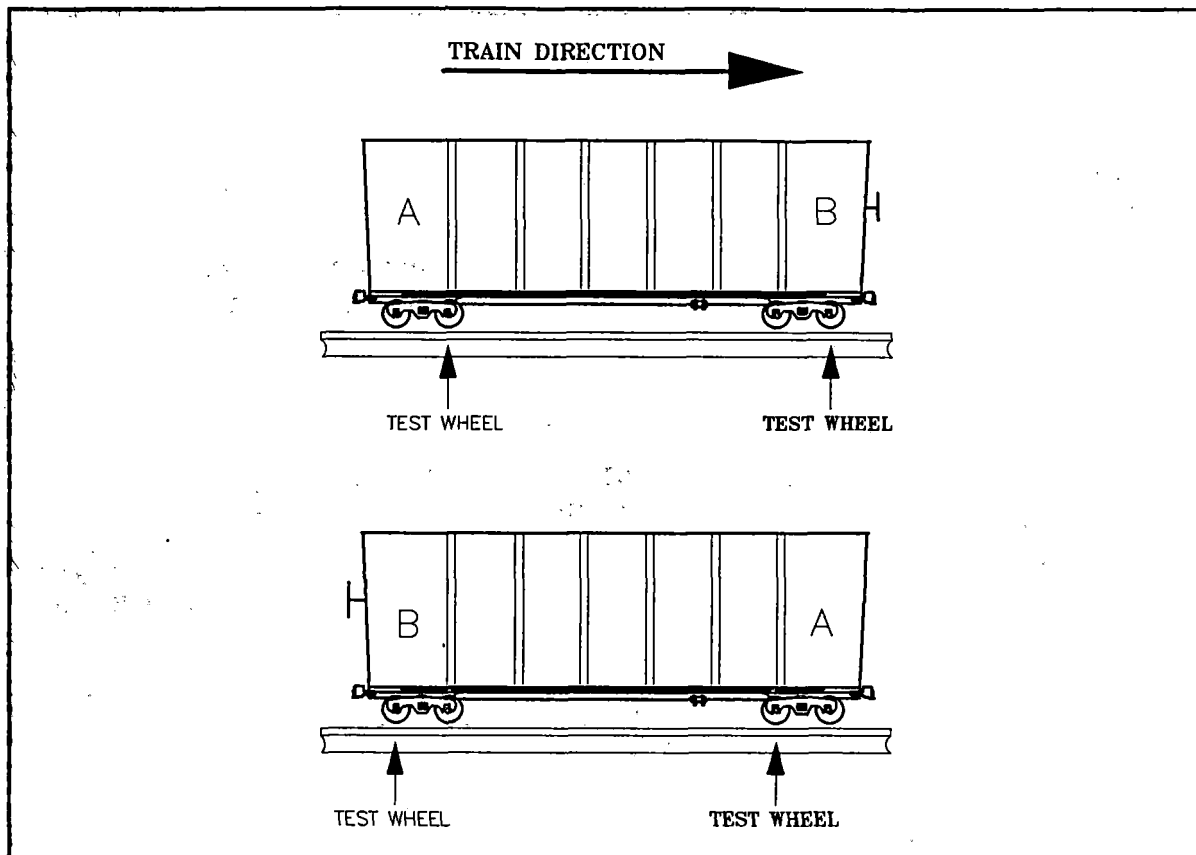


Figure 5. Wheel Set Position for Different Car Orientations

3.5 EXPERIMENT LIMITATIONS

The nature of the HAL consist operation and the HTL design imposed the following limitations on the design of the Wheel Performance Test:

- Unidirectional train operation resulted in the development of non-symmetric wheel profiles due to uneven exposure of the test wheels to all possible operating orientations relative to the rails of the HTL.
- The very uniform rail lubrication levels maintained on the HTL throughout the lubricated phase of the HAL program are atypical of those found in revenue service. Thus the effects of variable rail lubrication levels on wheel performance could not be investigated.

- Since brake applications were very limited, the effects of wheel tread braking on wheel performance could not be investigated.
- The HAL cars were only operated in the fully loaded condition at a uniform speed of 40 mph; therefore, the effects of varying speed and axle load conditions could not be addressed in the test.

3.6 INSTRUMENTATION

A wheel snap gage was used to determine changes in the flange thickness and rim thickness of the test wheels at one location on each wheel. As presented in Figure 6, the gage uses the same reference point on the wheel surface as the AAR Standard Steel Wheel Gage. The gage employs three dial indicators that have a resolution of 0.001 inch and provides an overall system accuracy of 0.005 inch. Snap gage measurements were collected at the mileage intervals given in Table 1.

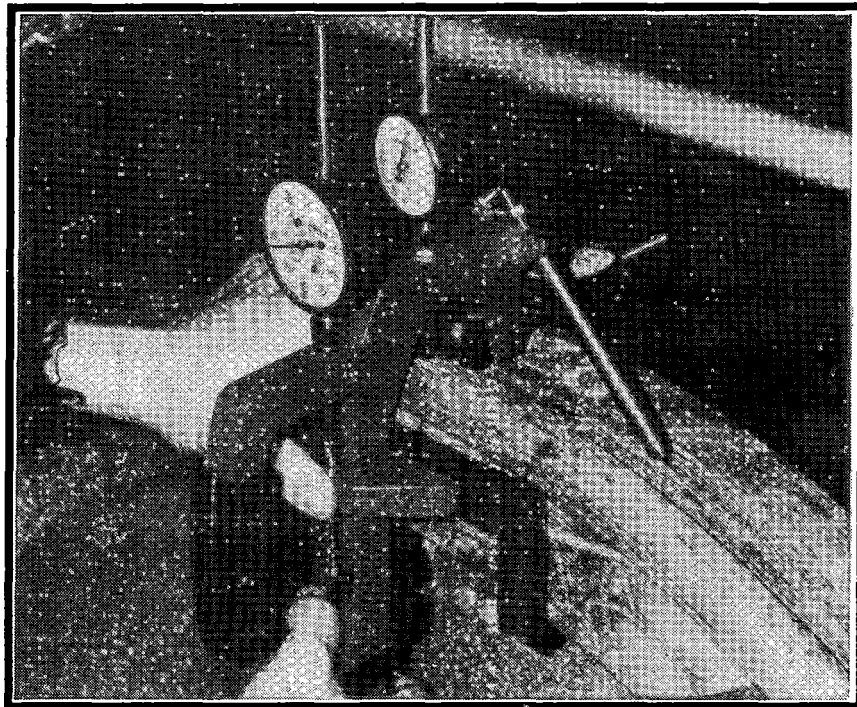


Figure 6. TTC Wheel Snap Gage

Table 1. Snap Gage Measurement Schedule

MEASUREMENT	ACCUMULATED MILEAGE
1	0
2	1,000+200
3	2,500+200
4	5,000+200
5	12,000+200
6	15,000+200
7	20,000+200
8	25,000+200
9	30,000+200

Brinell hardness measurements were made at two locations on the outer rim face of each test wheel prior to the start of on-track testing. The Brinell hardness values obtained on the test wheels were within the 321 Bhn to 363 Bhn range specified in AAR specification M-208-84, which covers cast wheels.

A longitudinal wheel profilometer, manufactured by Salient Systems, Inc., was used to measure the longitudinal profile of each of the wheel sets used in the Wheel Performance Test at the completion of the on-track testing (Figure 7). The profilometer measures instantaneous radial runout of each wheel while simulating rail contact by using a special shoe that diminishes the effects of shells on the wheel tread surface.

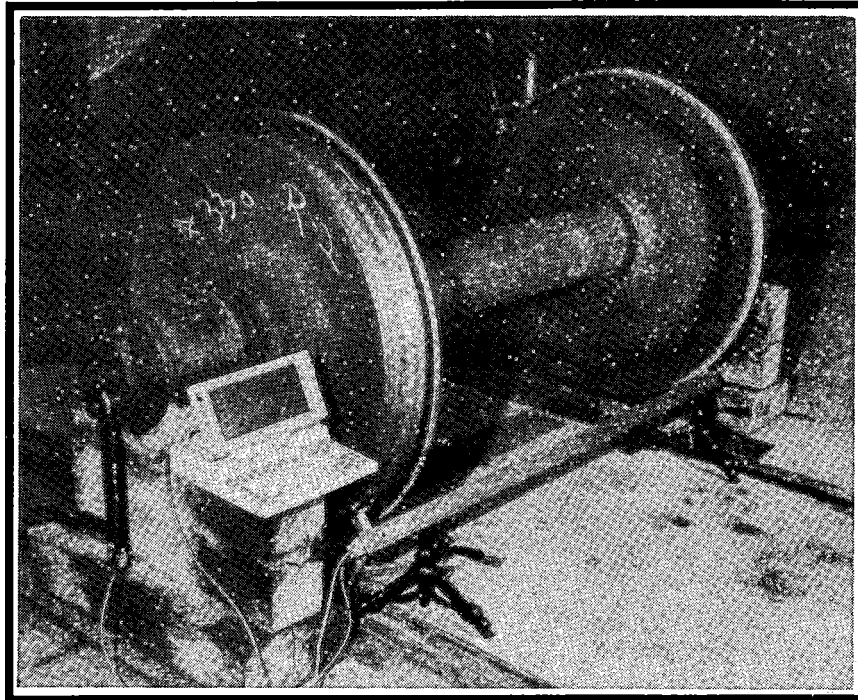


Figure 7. Longitudinal Wheel Profilometer System

The profilometer was also used to monitor the tread condition of the wheel sets of Car 330. Longitudinal profile measurements for Car 330 were obtained at the mileage intervals given in Table 2.

Table 2. Longitudinal Profile Schedule

MEASUREMENT	MILEAGE
1	1,500
2	3,000
3	15,000
4	23,500

A British Rail (BR) profilometer was used to document the lateral profile of the test wheels at the completion of the on-track tests (Figure 8).

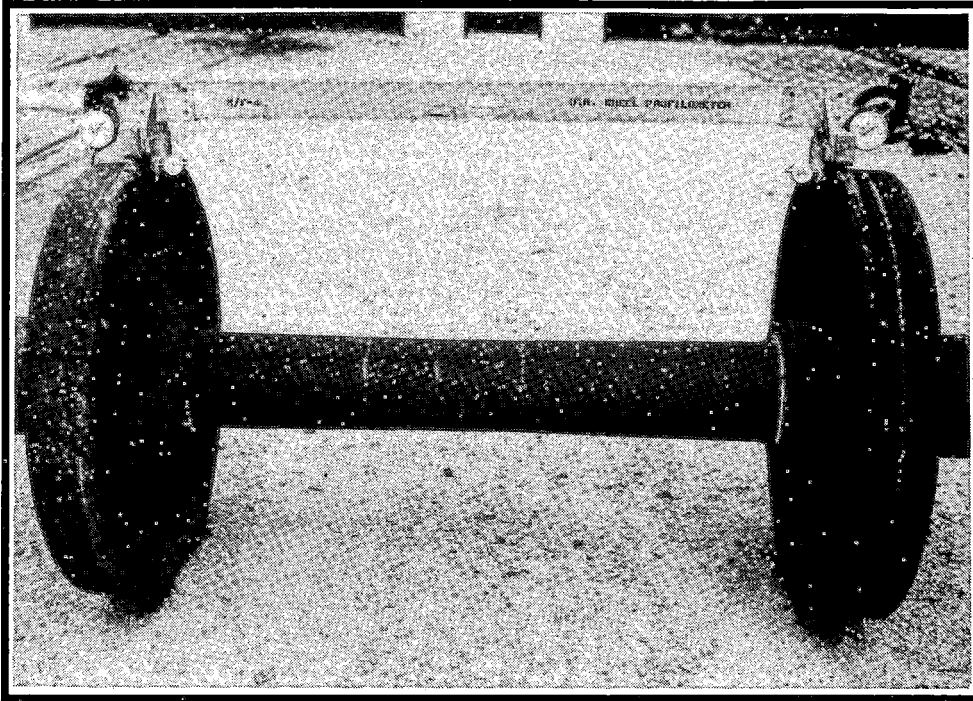


Figure 8. British Rail Profilometer System

4.0 TEST RESULTS

4.1 WHEEL PROFILE

As already discussed, the HAL consist was operated primarily in the counterclockwise direction around the HTL. The unidirectional operation resulted in the development of asymmetric profiles on the car wheels. Figure 9 shows typical profiles of a right and left wheel for a 33-ton axle load car obtained using the BR profilometer.

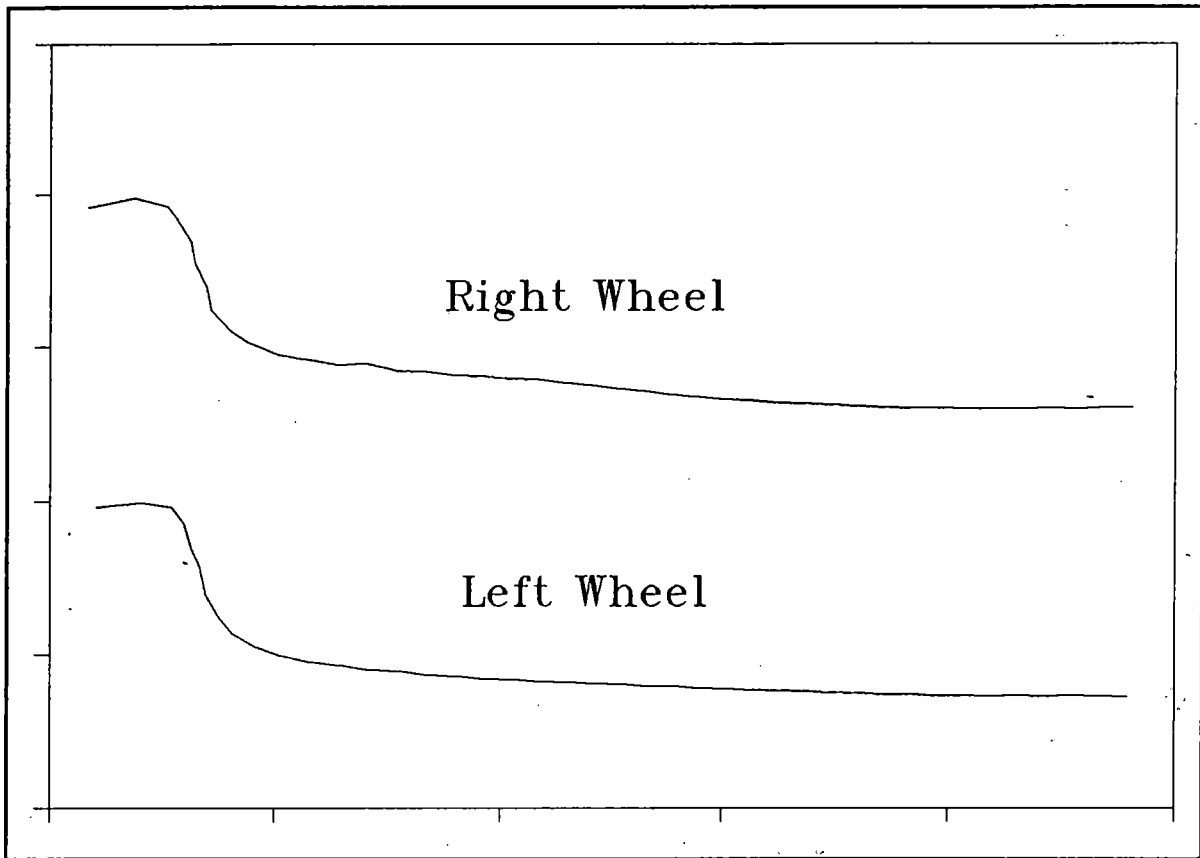


Figure 9. 33-Ton Axle Load Car Wheel Profiles

Inspection of Figure 9 shows that the profile of the right wheel, which operated on the inside rail of the HTL when in the lead axle position, is significantly different from the profile of the left wheel, which operated on the outside rail of the HTL when in the lead axle position, even though the wheels are mounted on the same axle.

Figure 10 shows typical profiles of a right and left wheel for a 39-ton axle load car also obtained using the BR profilometer.

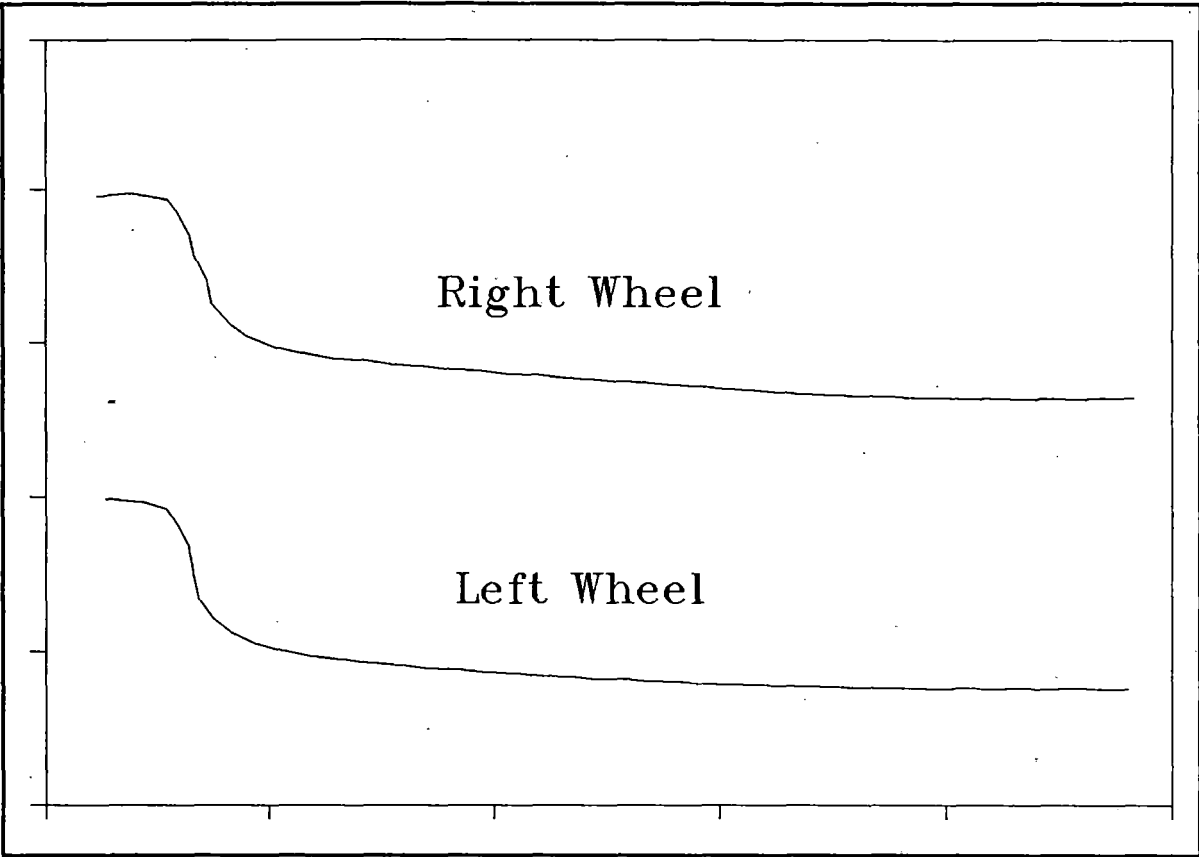


Figure 10. 39-Ton Axle Load Car Wheel Profiles

Comparison of Figures 9 and 10 shows that the 33- and 39-ton wheel profiles are similar in that, for both car sizes, the left wheel shows more loss of material from the flange and flange root areas resulting in an almost cylindrical wheel shape, while the right wheel shows more deformation and/or loss of material from the rim resulting in an exaggerated overall wheel conicity.

4.2 WHEEL PERFORMANCE

Cars used in the Wheel Performance Test completed 29,000 miles of operation during the program. Of the 29,000 miles, 3,500 were completed under dry rail conditions. During the lubricated phase of operation the outside rail of the HTL was lubricated using a wayside lubricator system located in Section 24 of the HTL. Lubrication levels around the loop were monitored using TTC's Lubrication Level Gage as described in Appendix A.

In addition, the wheel/rail coefficient of friction was measured periodically using a TTC tribometer. Table 3 provides a summary of typical wheel/rail coefficient of friction values measured in various locations around the HTL.

Table 3. Wheel/Rail Coefficient of Friction Values Measured at Various Locations on the HTL

Location	Inside Rail Head	Inside Rail Gage Face	Outside Rail Head	Outside Rail Gage Face
Sec. 03	0.45	NA	0.33	0.20
Sec. 07	0.50	0.35	0.36	NA
Sec. 25	0.35	NA	0.30	0.15
Sec. 31	0.35	NA	0.35	0.20

Due to the design of HTL, with nearly 78 percent of the track composed of curves and spirals, accelerated flange wear rates are achieved, and in the 29,000 miles of operation approximately 90 percent of the available flange material was used up on the wheels. The rate of rim wear achieved on the HTL is not significantly accelerated over that obtained in revenue service. During the 29,000 miles of operation approximately 10 percent of the available rim material was used up on the wheels.

FLANGE WEAR

In order to evaluate the wear data collected for the 33- and 39-ton axle load cars, given the differences observed in the right and left wheel profiles, an analysis of flange and rim wear by car side for each car type was performed. The mean value of the flange and rim loss was determined for right and left wheel positions for each car type. Figures 11 and 12 are graphical representations of the mean flange loss data.

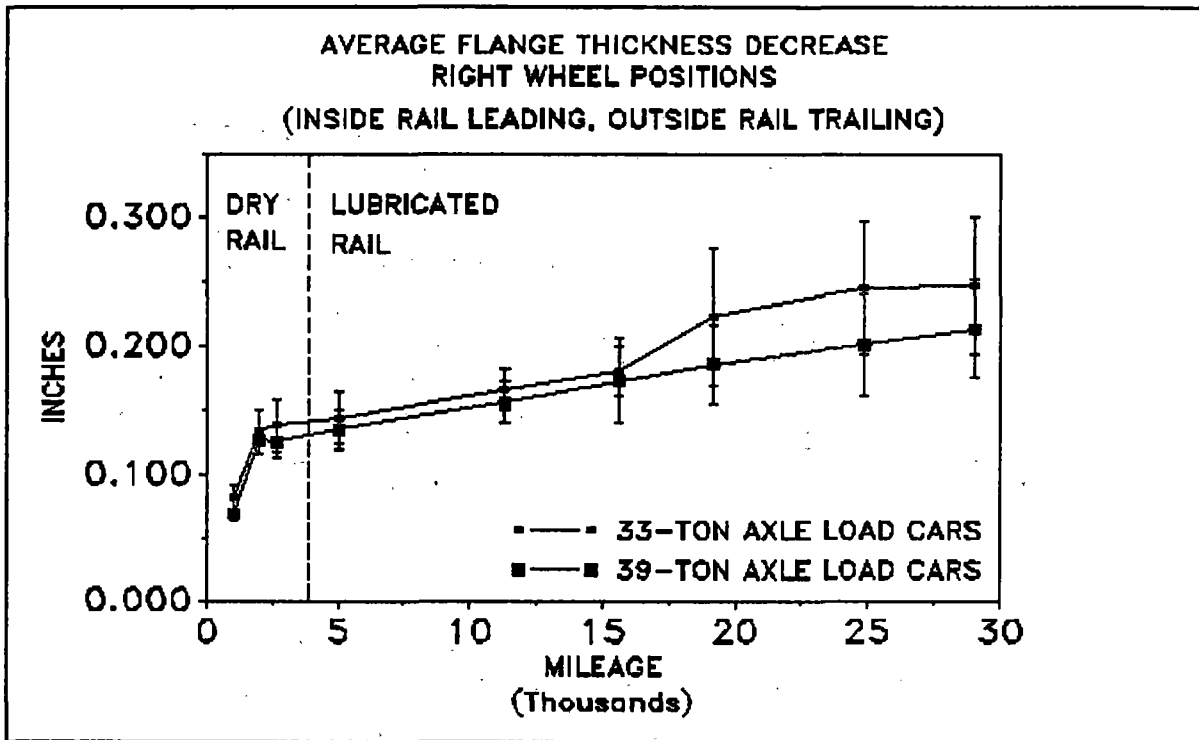


Figure 11. Mean Flange Loss as a Function of Car Mileage - Right Wheel Positions

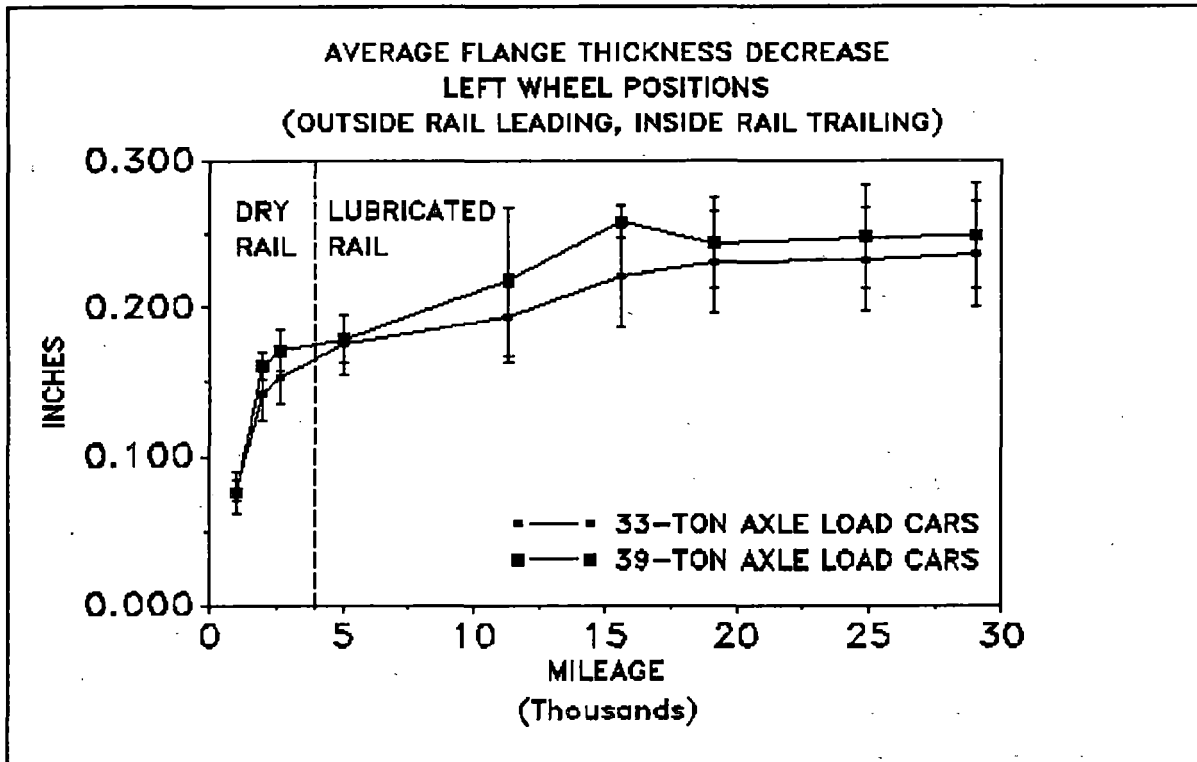


Figure 12. Flange Loss as a Function of Car Mileage - Left Wheel Positions

Examination of Figures 11 and 12 reveals that accelerated flange wear occurred during the initial 2,500 miles of operation under dry rail conditions as the wheels wore to a profile that conformed to the HTL rail profile. After the initial break-in period, the rate of wear slowed appreciably for both car types. It should be noted that the wear rates obtained, given the rail lubrication conditions as previously described, are comparable for the 33- and 39-ton axle load cars. The small vertical bars associated with each data point are included as a graphical representation of the scatter obtained in the measurement. The length of the bar represents the standard deviation from the mean value obtained from the measurement.

An Analysis of Variance was performed of the flange loss data, and it was determined that on a car mileage basis there was no statistically significant difference in the data obtained for the two car types.

It may seem unusual that a 19.3 percent increase in axle load did not result in a similar increase in the flange wear rate; however, the results obtained in this test are consistent with results obtained from previous tests conducted at the TTC. In 1981, as part of the FAST program, a Variable Axle Load Test (VALT) was conducted to determine the relationship between axle loading and wheel wear.¹ The test used sixteen 33-ton axle load cars equipped with new Class U wheels machined to an AAR 1:20 profile. The axle loading was varied as indicated in Table 4.

Table 4. VALT Axle Loading Summary

NUMBER OF CARS	AXLE LOADING
2	8.00 tons/axle
4	16.25 tons/axle
2	24.50 tons/axle
2	28.00 tons/axle
2	33.00 tons/axle
4	35.50 tons/axle

The cars were operated for 14,000 miles under dry rail conditions and 70,000 miles under lubricated rail conditions. Snap gage data were collected at 1,000 mile intervals during the dry rail operation phase and at 7,000 mile intervals during the lubricated rail operation phase.

Results from the experiment, illustrated in Figure 13, showed that the effects of axle loading on flange wear diminished as axle loading exceeded 28 tons.

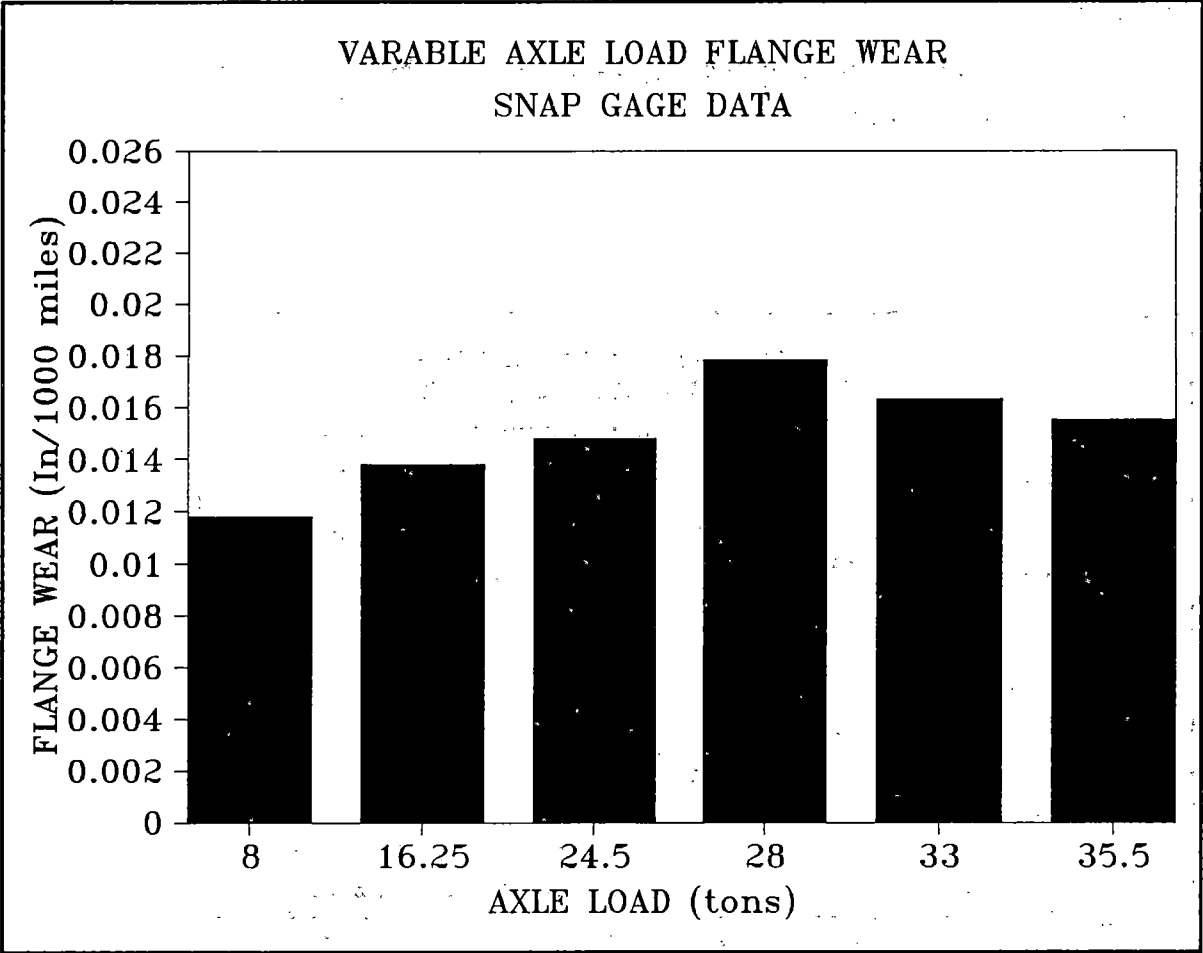


Figure 13. Flange Wear with Axle Load

TREAD WEAR

Figures 14 and 15 are graphical representations of the mean rim loss data obtained during the HAL experiment.

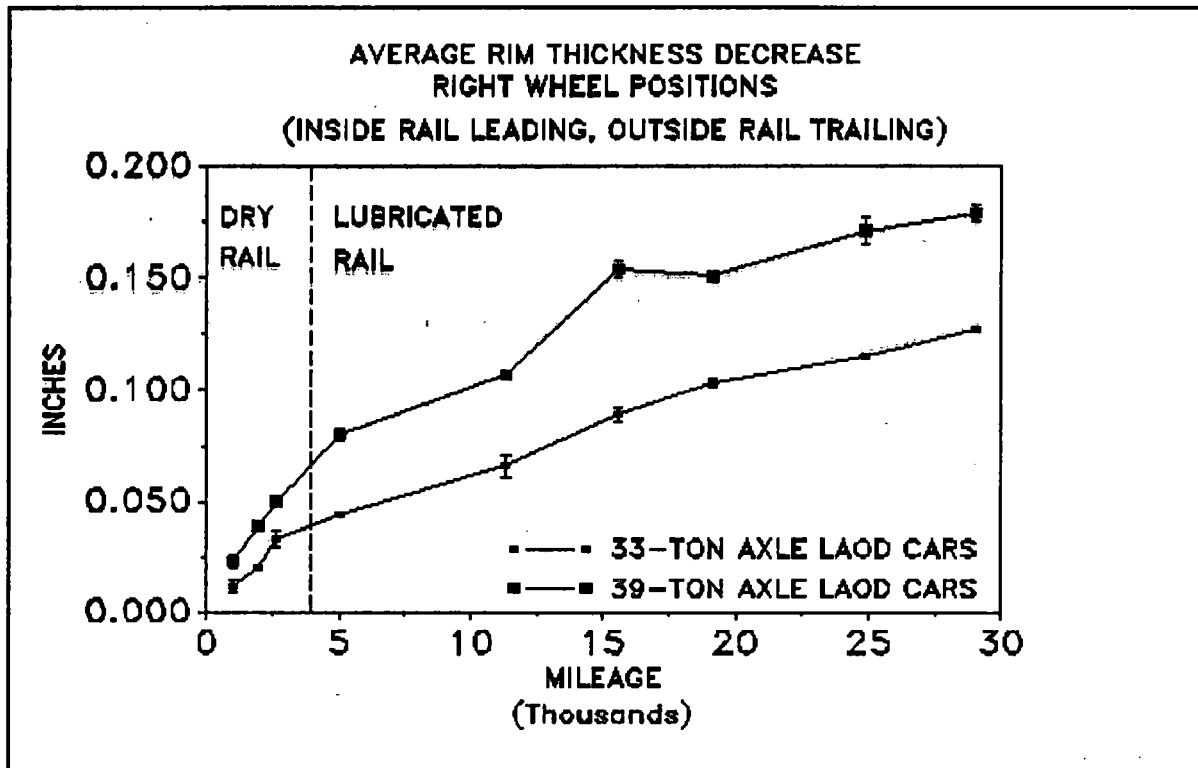


Figure 14. Mean Rim Loss as a Function of Car Mileage - Right Wheel Positions

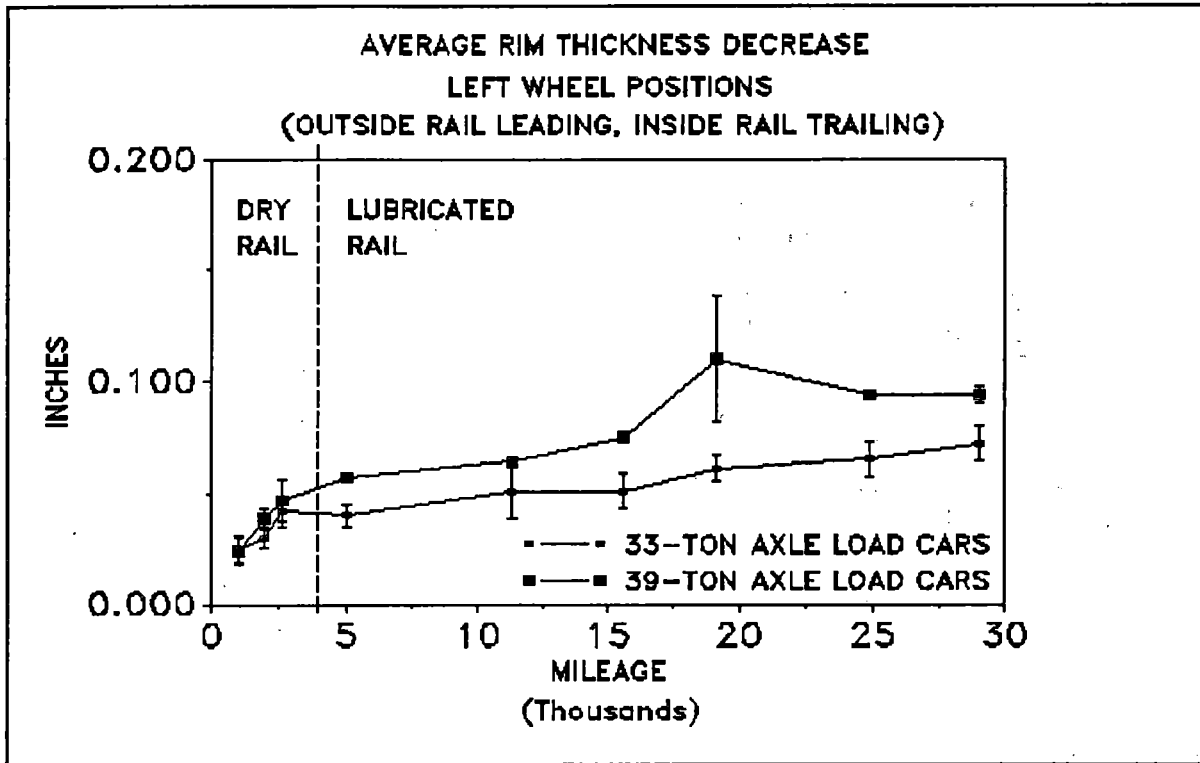


Figure 15. Mean Rim Loss as a Function of Car Mileage - Left Wheel Positions

Examination of Figures 14 and 15 shows that accelerated rim wear occurred during the initial 2,500 miles of operation under dry rail conditions as the wheels wore to a profile that conformed to the HTL rail profile.

After the initial break-in period, the rate of wear slowed for both car types. Initially the rate of rim wear was higher for the 39-ton axle load cars, but by the completion of the on-track tests the rim wear rates for both car types were quite similar. An Analysis of Variance was also performed on the rim loss data. Results of the analysis indicated that after the initial break-in period during dry rail conditions there was no statistically significant difference in the wear rate obtained for the two car types.

4.3 WHEEL TREAD CORRUGATION

After the wheel sets were replaced in February 1989, Car 330 completed 23,500 miles of operation. Figures 16, 17, and 18 are graphical representations of the wheel corrugation data for Car 330. Figure 16 shows the corrugations observed on the Class B wheels of axle 1 removed in February 1989.

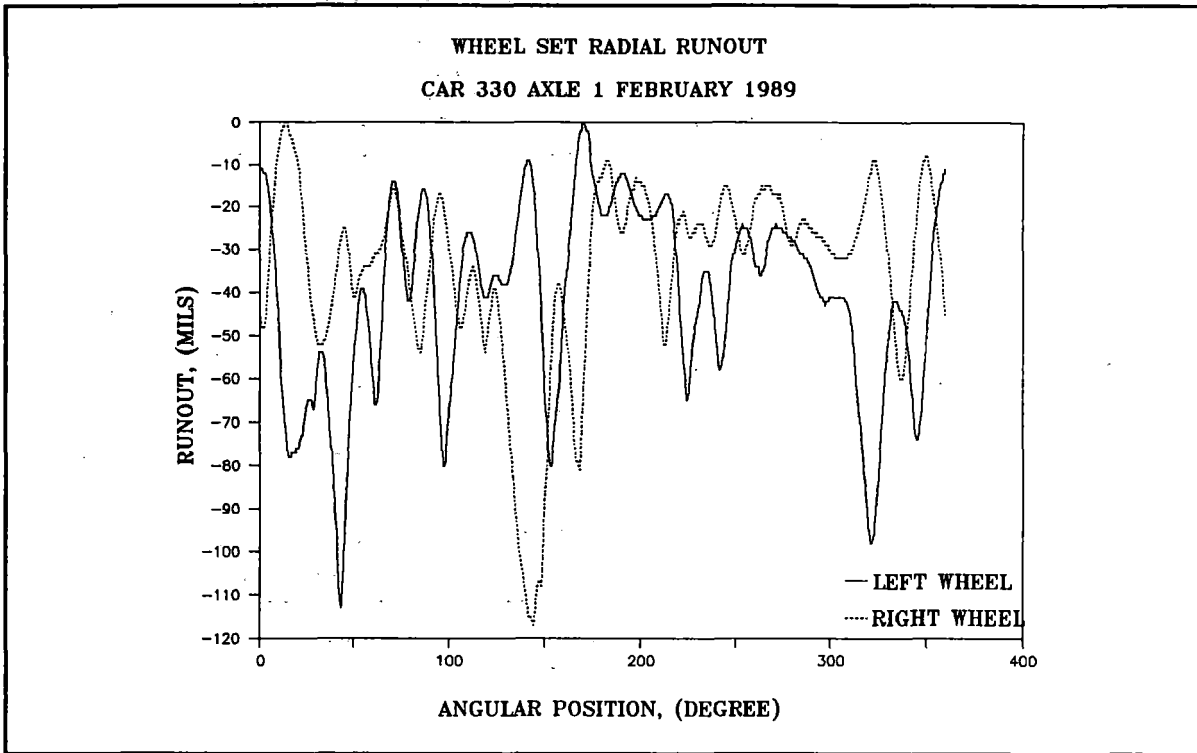


Figure 16. Longitudinal Profile of Initial Wheel Set Equipped with 38 Inch Diameter AAR Class B Wheels Removed from Car 330 in February 1989

Examination of Figures 17 and 18 shows that corrugations developed on the right wheel of axle 1, a Class C wheel, within the initial 1,500 miles of operation but that their severity did not increase with accumulation of additional mileage.

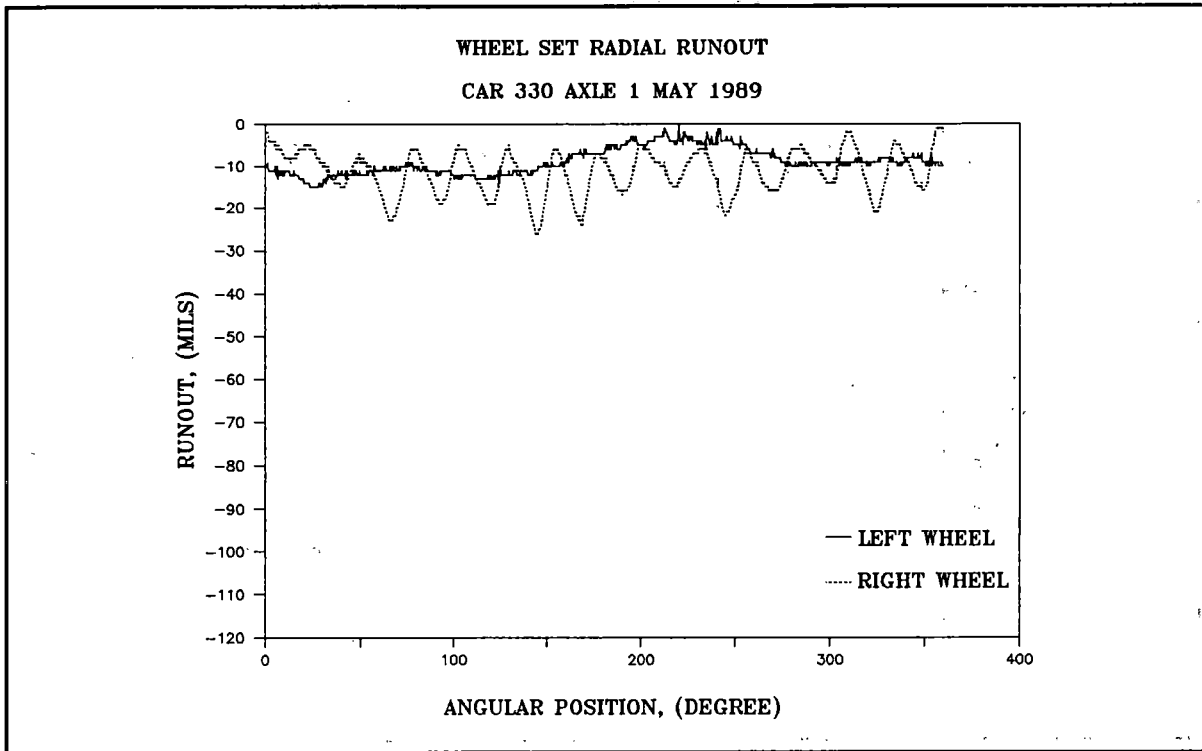


Figure 17. Longitudinal Profile of Replacement Wheel Set Equipped with 38 Inch Diameter AAR Class C Wheels from Car 330 after 1,500 Miles of HTL Operation

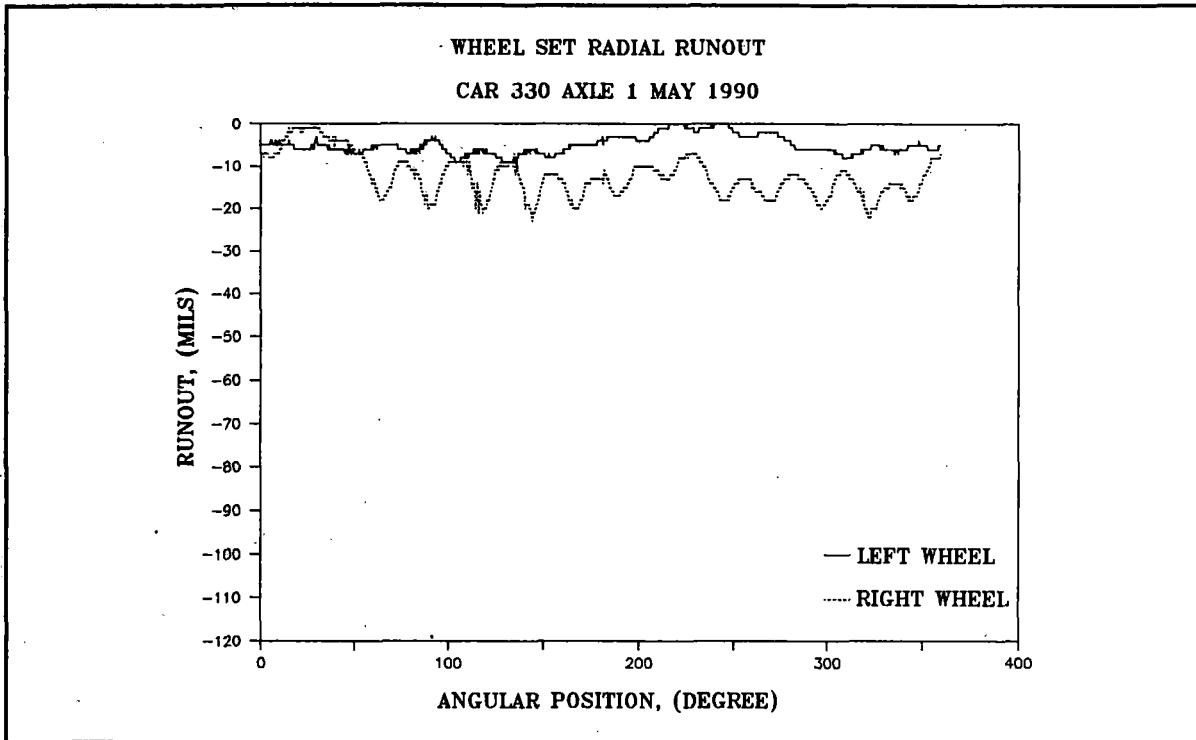


Figure 18. Longitudinal Profile of Replacement Wheel Set from Car 330 at Completion of 23,500 Miles of HTL Operation

The new Class C wheels installed in the 33- and 39-ton axle load cars used in the Wheel Performance Test also developed corrugations over the course of the program. The corrugations were similar in appearance for both car types. A graphical representation of the wheel corrugation data for one of the 33-ton axle load wheel sets and one of the 39-ton axle load wheel sets used in the Wheel Performance Test are provided in Figures 19 and 20.

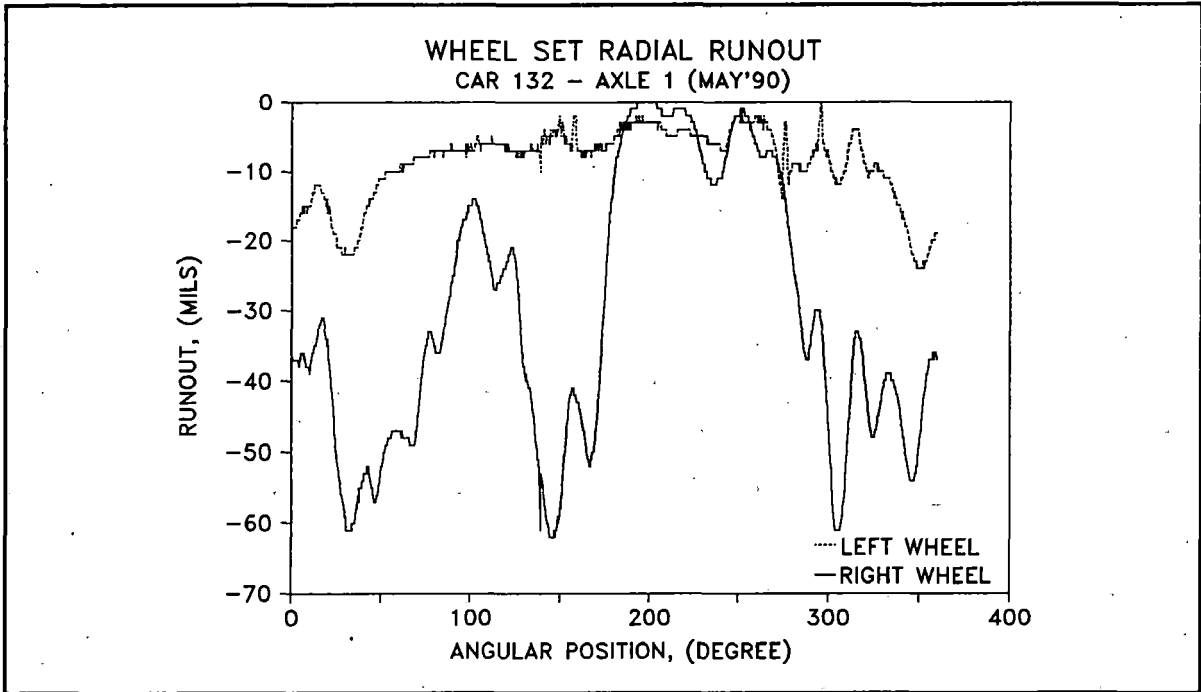


Figure 19. Profile of a 33-Ton Axle Load Wheel Set with 36-Inch-Diameter Wheels

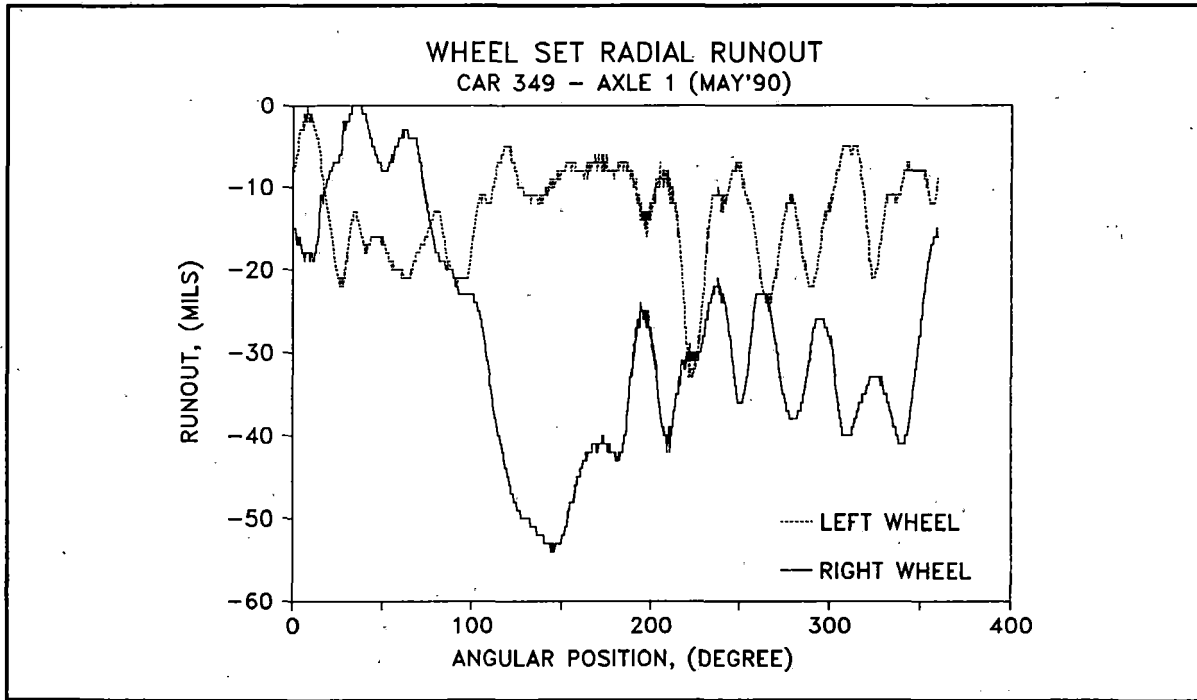


Figure 20. Profile of a 39-Ton Axle Load Wheel Set with 38-Inch-Diameter Wheels

Examination of Figures 19 and 20 shows that the corrugations are similar in spacing and severity for the 33- and 39-ton axle load car wheel sets.

Periodic inspections of the HAL consist revealed a steady decrease in the number of corrugated wheels from an initial value of approximately 10 percent to a final value of less than 3 percent by the completion of the on-track tests.

Another observation noted during the inspections was the development of plastic deformation of the tread surface on the right wheel of axle positions 1 and 3 and the left wheel of axle positions 2 and 4 on many of the wheel sets in the HAL consist including the locomotive wheel sets.

Metallurgical evaluation of the wheels removed from HAL Cars 330 and 335 revealed excessive metal flow and plastic deformation on the corrugated wheels with cracks originating at the surface and propagating in the direction of the deformation. The mate wheels showed significantly less metal flow and no cracking. There was no evidence of thermal input due to wheel sliding or prolonged tread braking on any of the wheels. Figure 21 is a photomicrograph of an axial cross section through a corrugation from a wheel removed from Car 335 which shows the deformation (top right) and the cracking (top left and center).

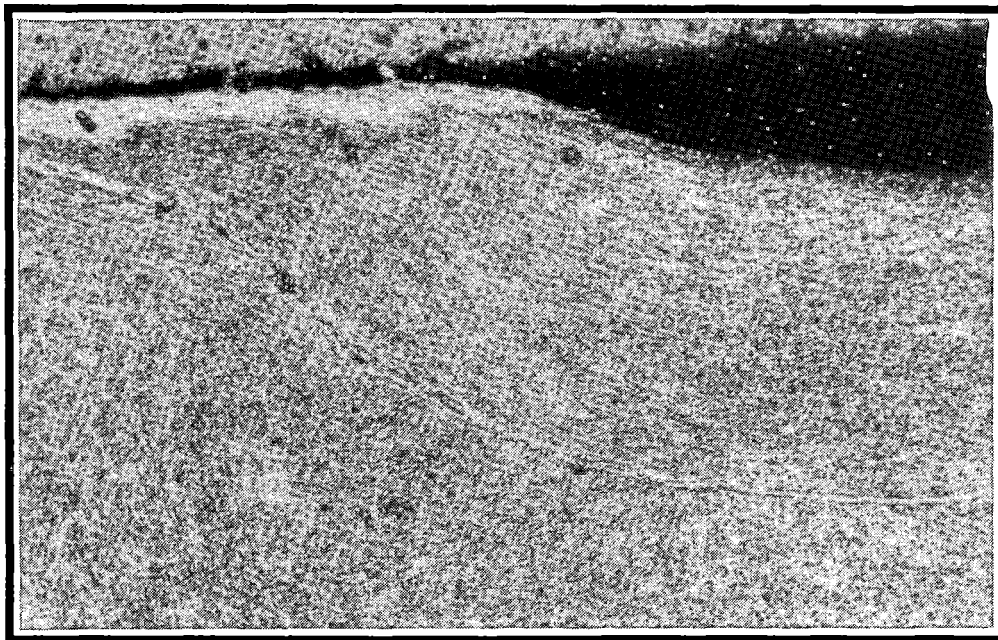


Figure 21. Axial Cross Section of Corrugated Wheel Removed from Car 335

5.0 CONCLUSIONS

5.1 WHEEL PERFORMANCE

Given the experiment design limitations previously discussed, the following conclusions can be drawn from the wheel performance data:

- On a car mileage basis there was no statistically significant difference in the flange wear data obtained for the two car types. It should also be noted that due to differences in wheel circumference, the 39-ton axle load cars completed approximately 5 percent fewer revolutions per mile than the 33-ton axle load cars.
- There is no statistically significant difference in the rim wear data obtained after the initial break-in period for 33- and 39-ton axle load cars used in the test. However, the amount of rim wear achieved during the experiment represents only about 10 percent of the rim material available for the wheel designs tested.
- It is suspected that the plastic deformation observed on the wheel tread surfaces of both car types was caused in part by the nature of the HAL train operation and the design of the HTL.

5.2 WHEEL TREAD CORRUGATION

Since corrugations were observed on the wheels of both 33- and 39-ton axle load cars and corrugated wheels have not been reported as a problem occurring on 33-ton axle load cars currently operating in revenue service, it appears that the corrugations occurred due to the nature of the HAL consist operation and the design of the HTL. At this time it does not appear that the corrugations are associated with the increased axle load condition.

6.0 RECOMMENDATIONS

Based on the results of the wheel performance experiment, the following course of action will be pursued during the next phase of the HAL program:

- Continue the Mechanical Component Performance Experiment so that the performance of locomotive and car components can be monitored during

the 100 MGT extension of the HAL program. During the next 100-MGT period, the HAL consist will be operated in both the clockwise and counterclockwise directions around the HTL.

- As part of the experiment, conduct a Wheel Performance Test using three fully loaded 39-ton axle load cars and three fully loaded 33-ton axle load cars equipped with AAR Class C, two wear cast steel wheels machined to an AAR1B profile to document wheel performance under bidirectional operating conditions including the occurrence of plastic deformation on the tread of the wheels.
- Quantify wheel wear on every wheel of each test car through periodic wheel profilometer and wheel snap gage measurements.
- Install special air brake control equipment on a selected number of cars so the effects of cyclic tread braking on wheel performance can be investigated.

REFERENCES

1. **Leary, John F., Kenneth C. Rownd and Roy A. Allen. "Mechanical and Material Aspects of Wheel Wear at FAST," Unpublished.**

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.

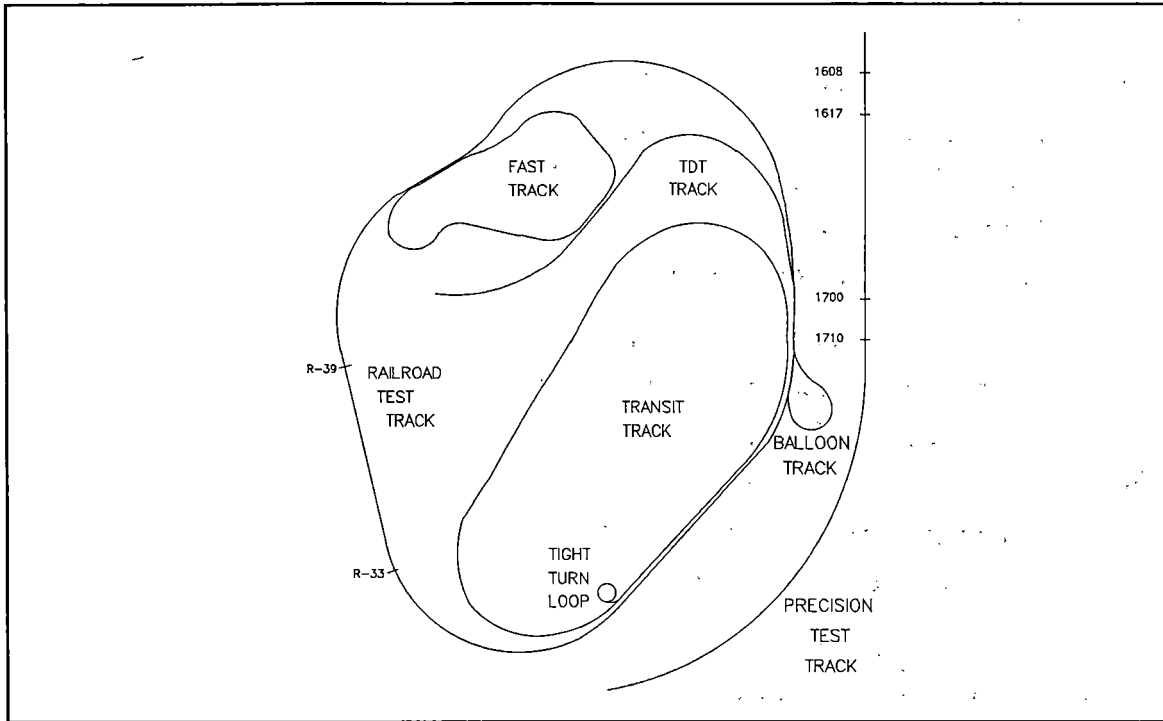


Figure 1. Test Tracks at High Speed Ground Test Center, Pueblo, CO, Showing General Location of FAST

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.

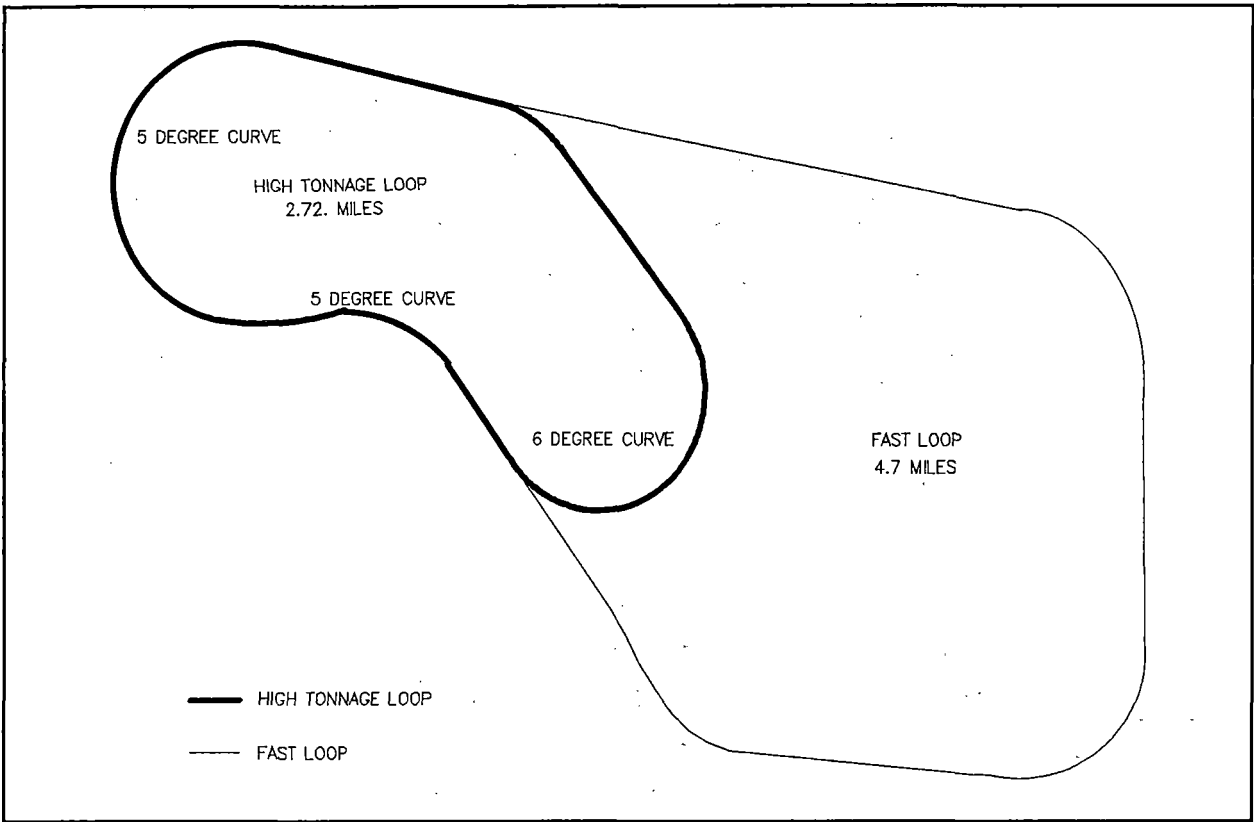


Figure 2. High Tonnage Loop

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.

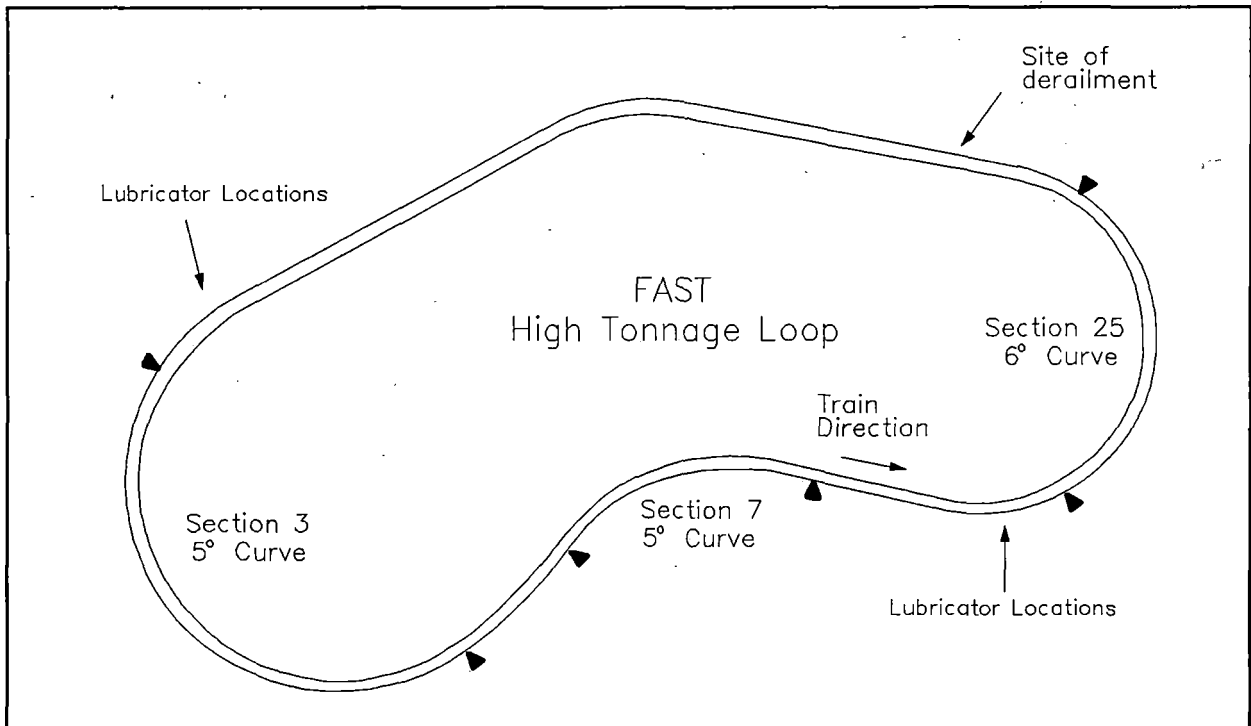


Figure 3. Lubricator Locations on the High Tonnage Loop

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.

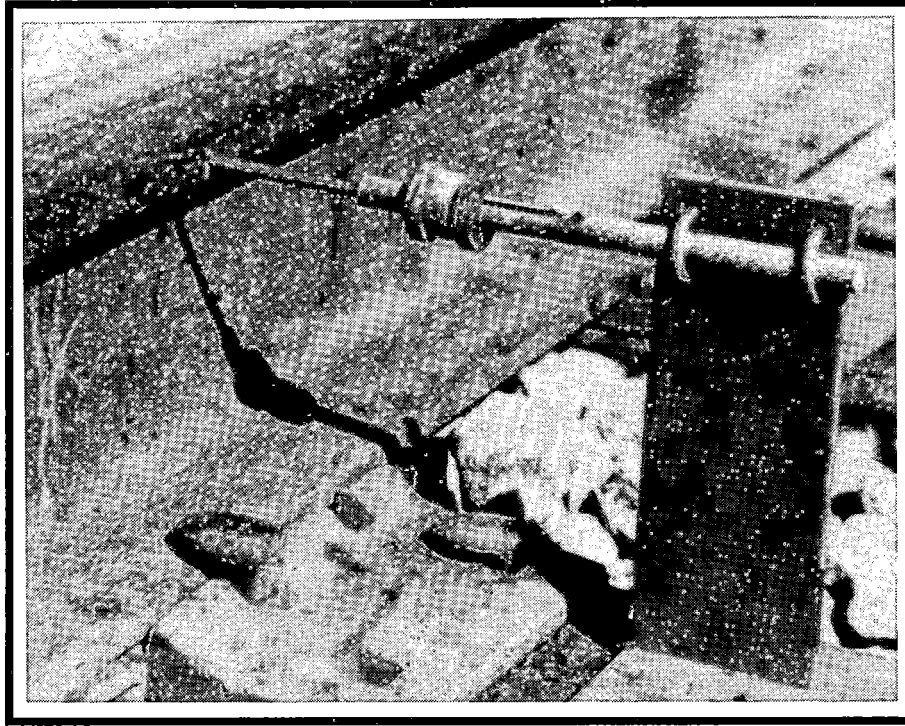


Figure 4. Tell Tale Installed on the HTL

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.

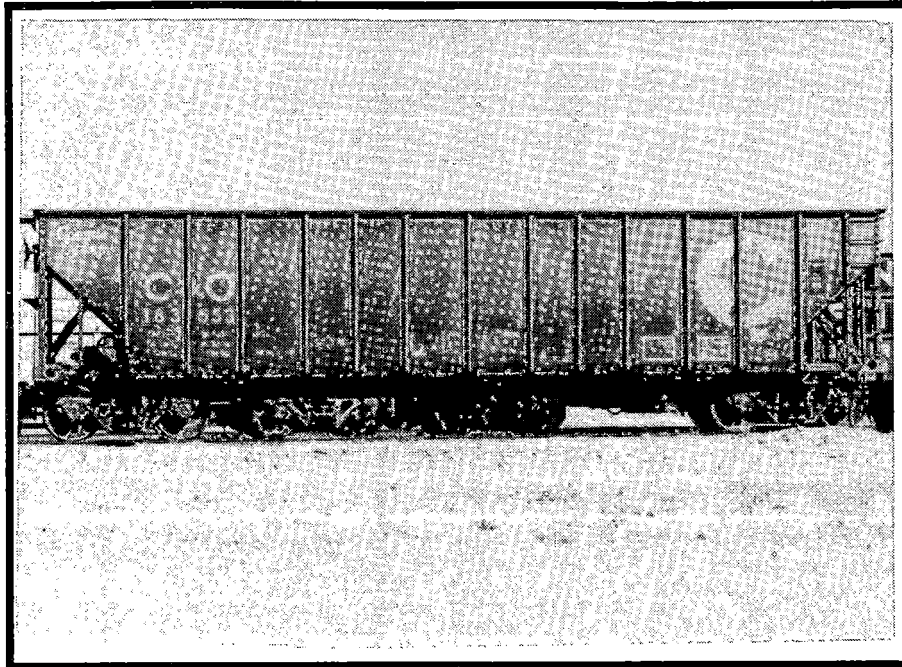


Figure 5. Typical 100-ton Capacity Car

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.

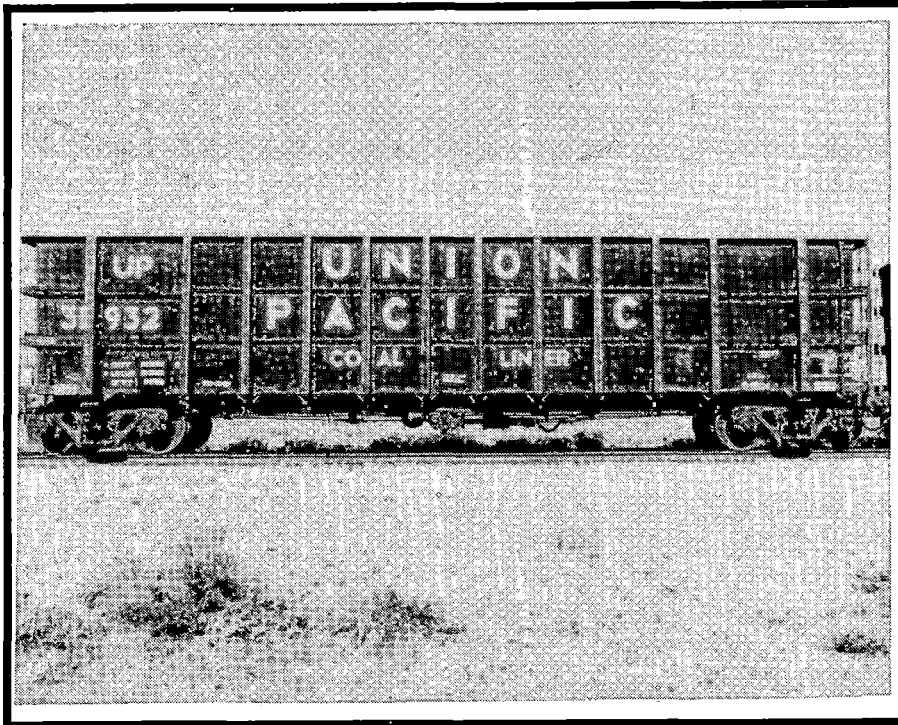


Figure 6a. Typical 125-ton Capacity Open Top Gondola

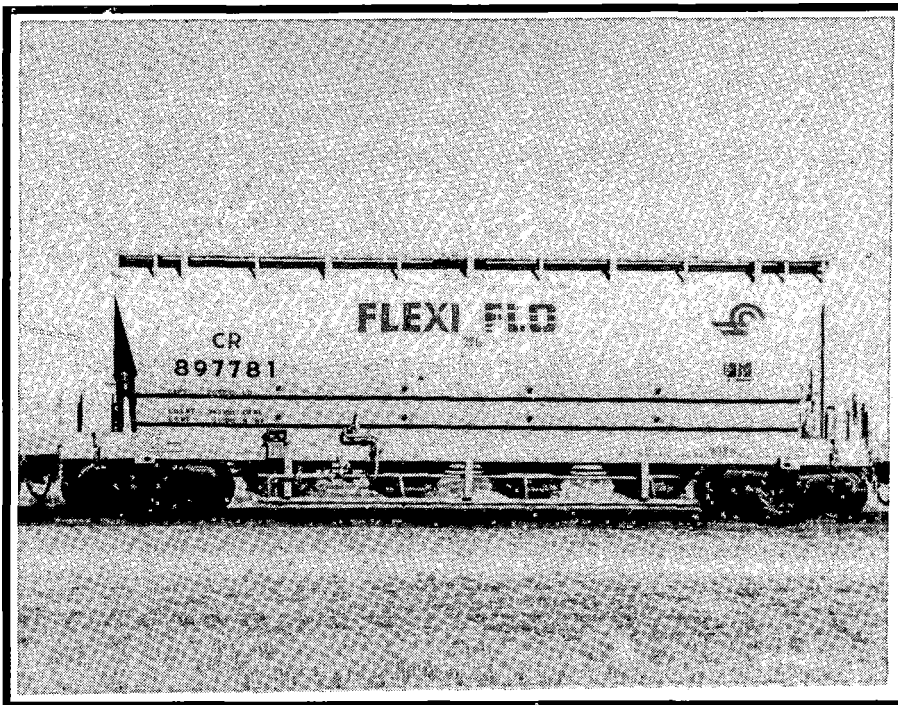


Figure 6b. Typical 125-ton Capacity Covered Hopper Car

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.

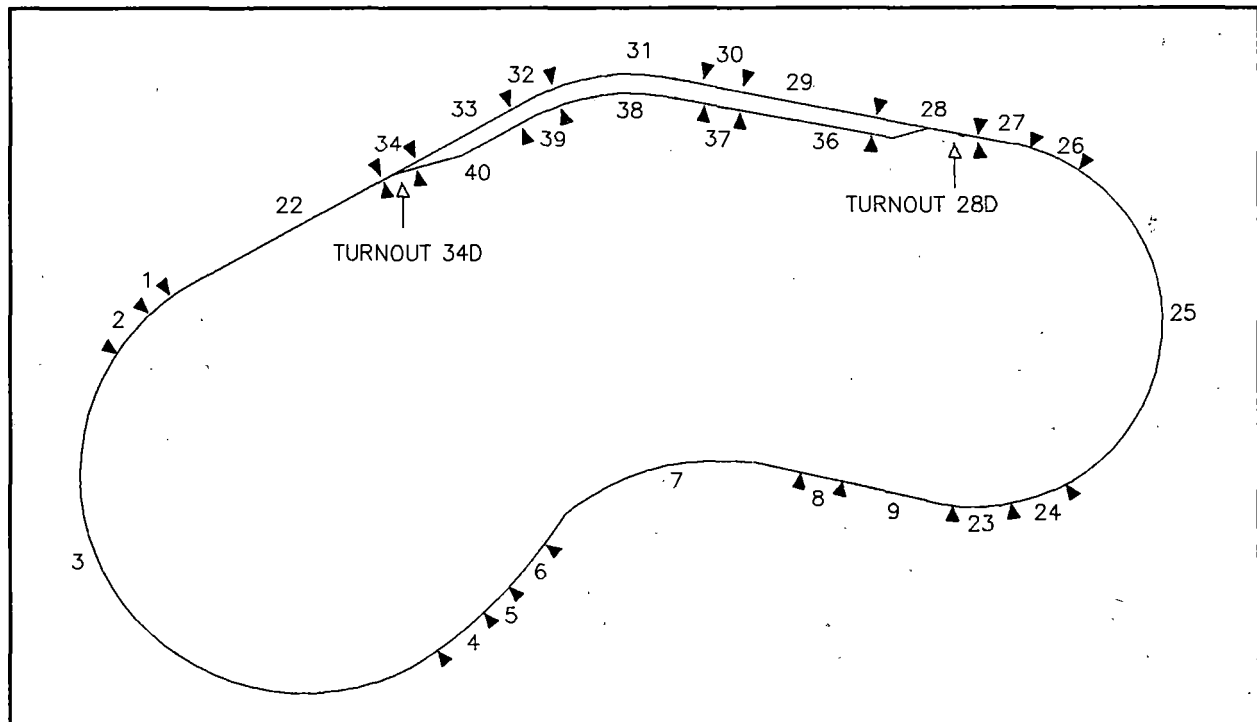


Figure 7. Map of HTL with By-Pass Track Added at Start of HAL Operations

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.

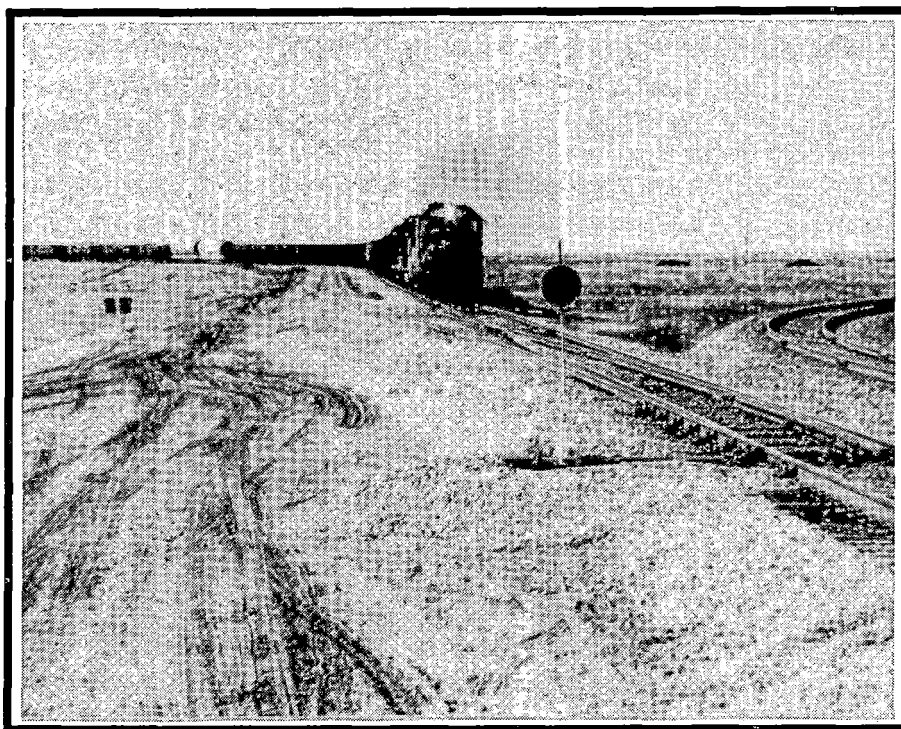


Figure 8. Typical HAL Train in Operation

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.

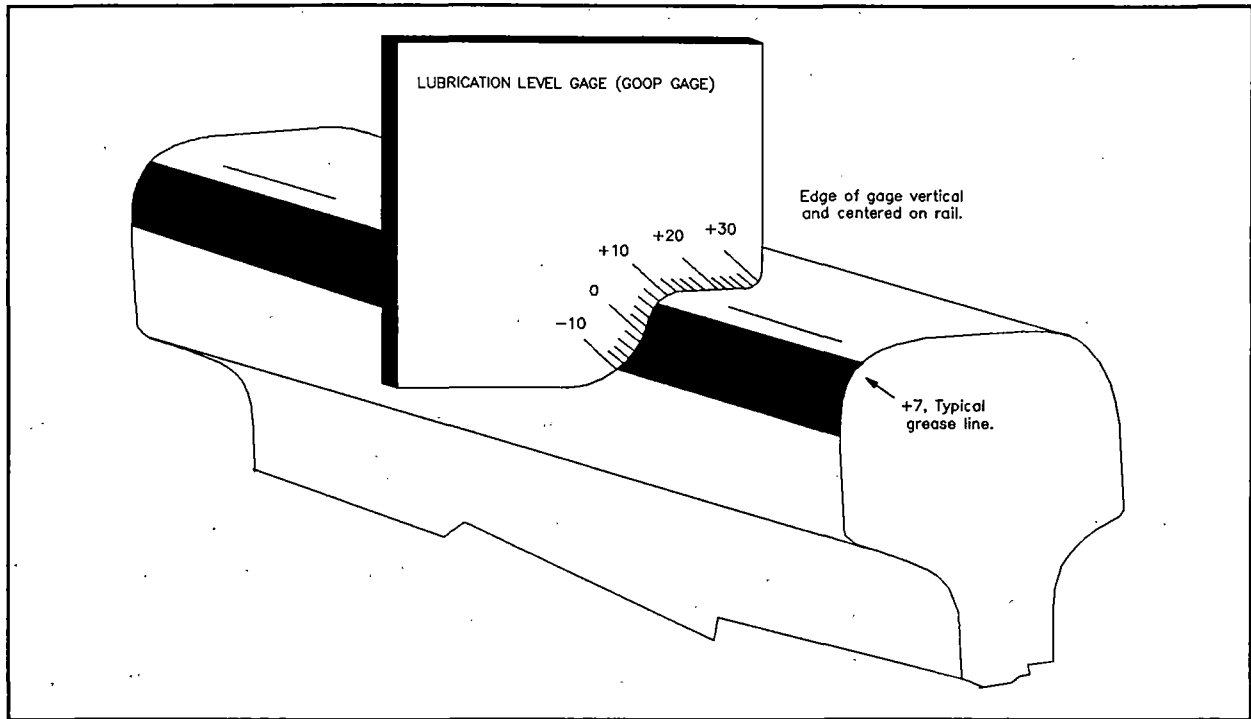


Figure 9. TTC's Lubricant Level Gage (Goop Gage)

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.

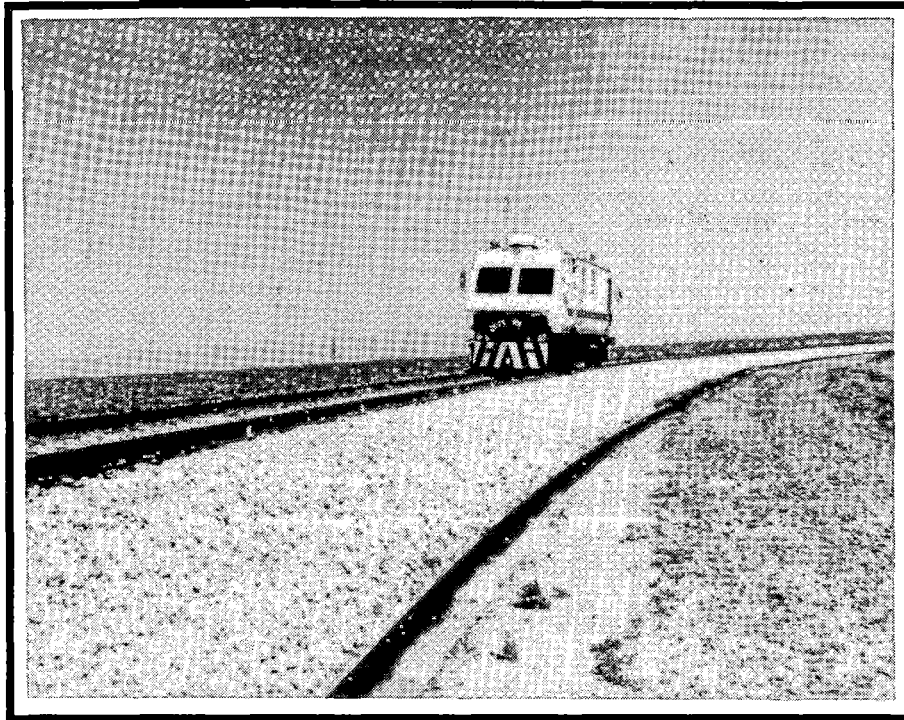


Figure 10. EM80 Track Geometry Car

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.

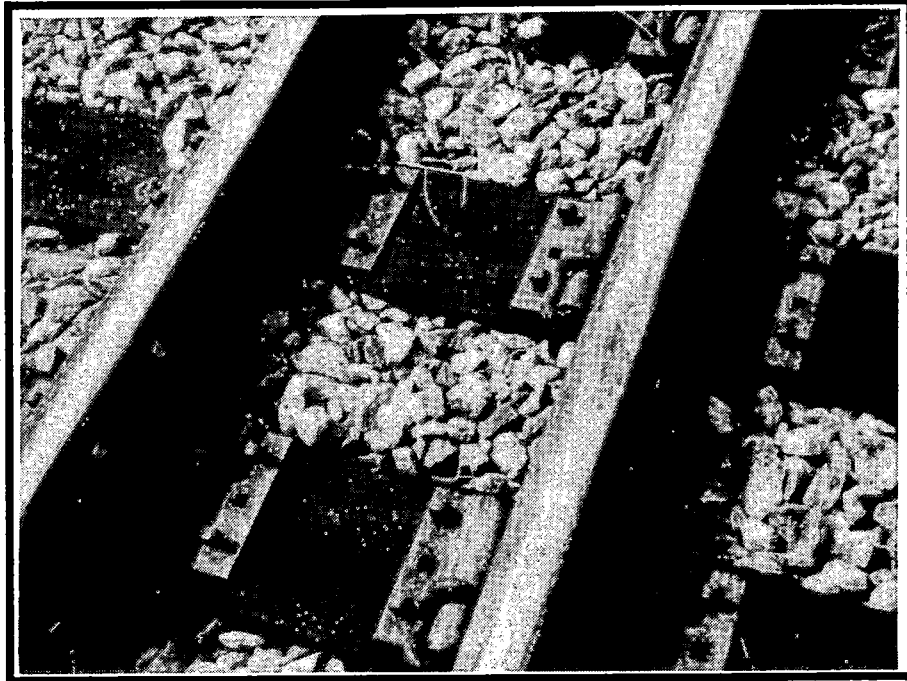


Figure 11. Typical Welded Rail Joint Batter

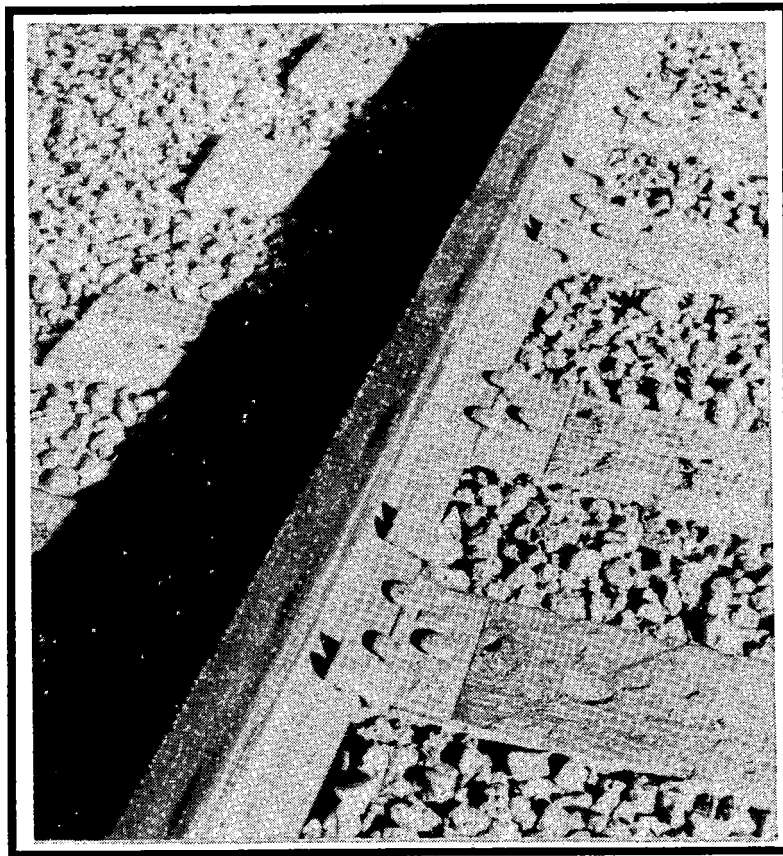


Figure 12. Typical Corrugations

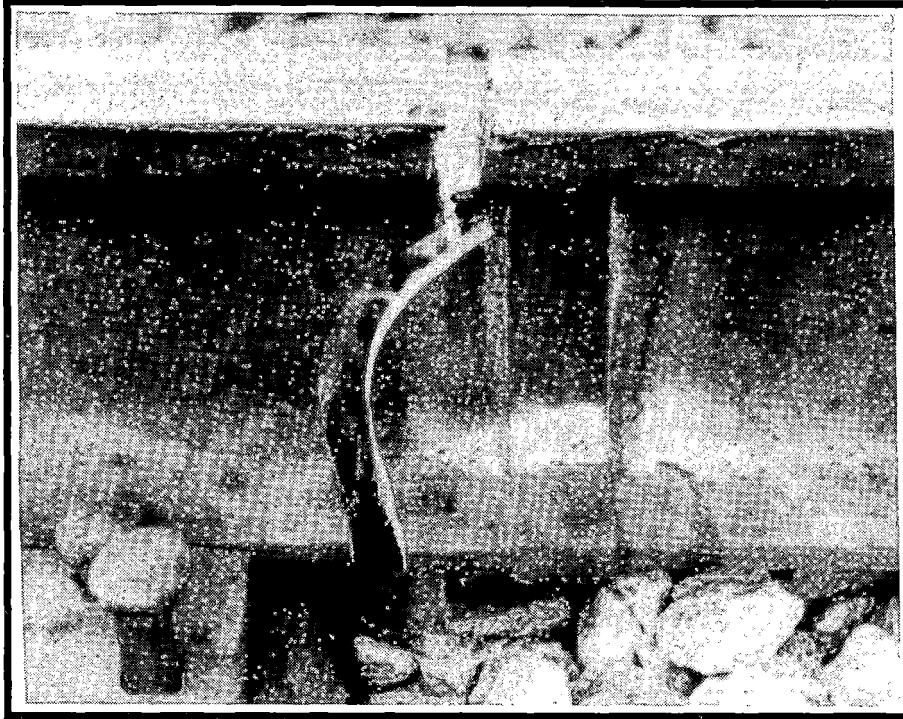


Figure 13. Typical Broken Field Weld

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.

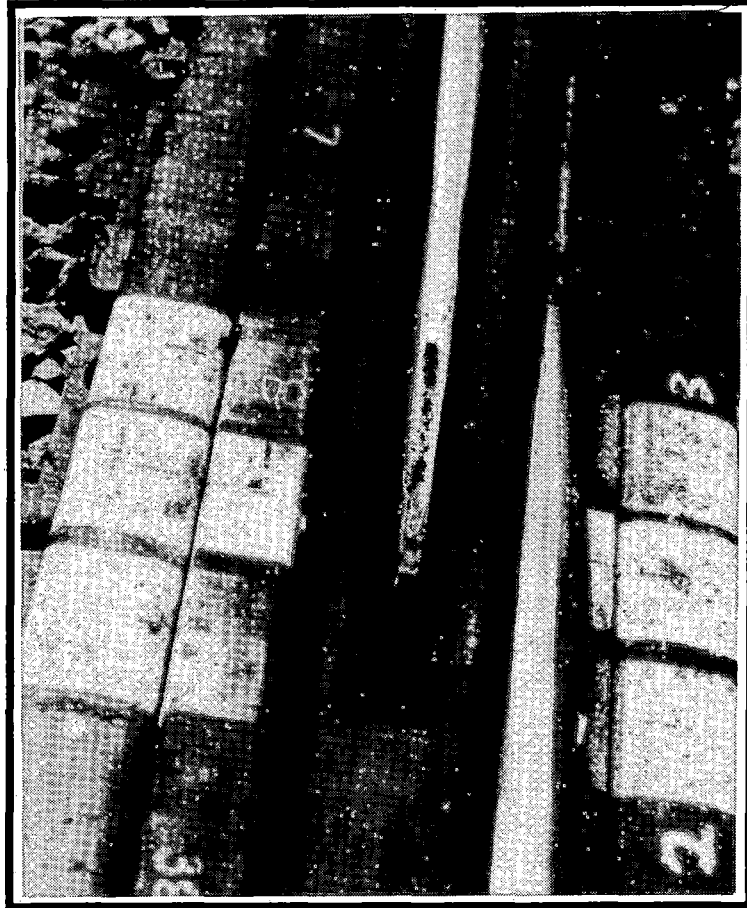


Figure 14. Typical Worn Frog Components

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.

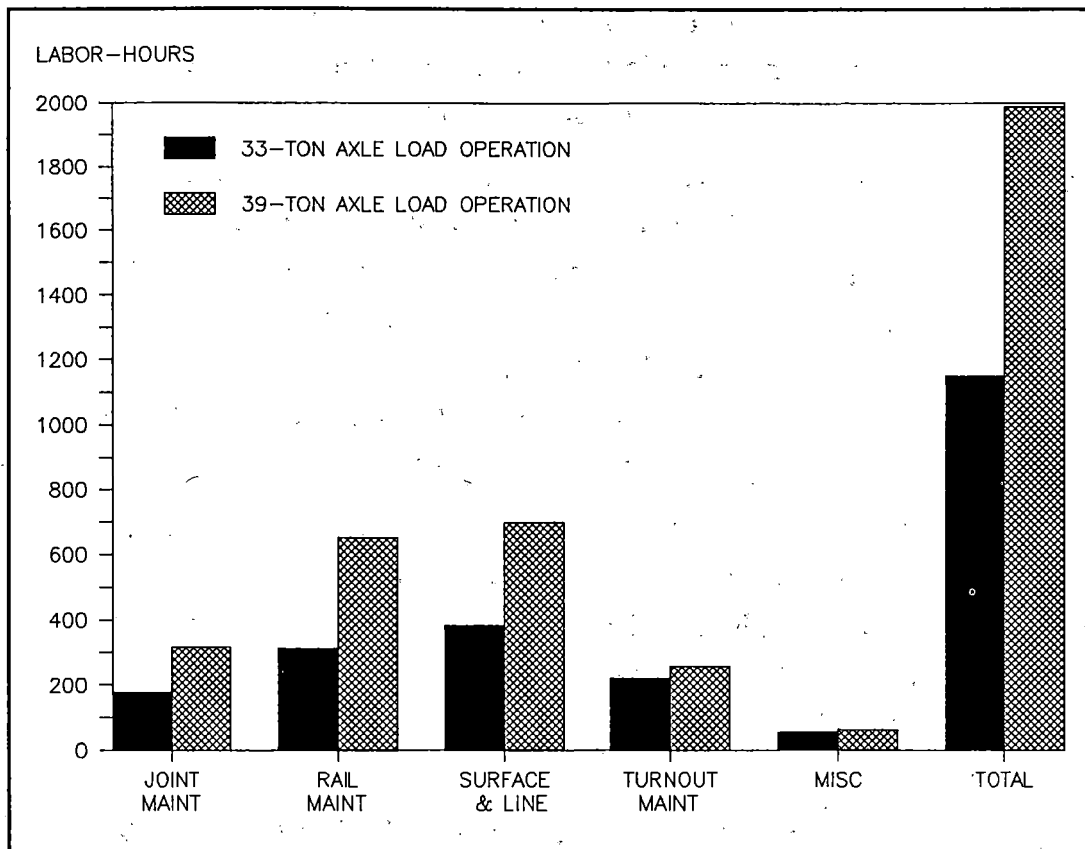


Figure 15. Breakdown of Track Maintenance Effort

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.

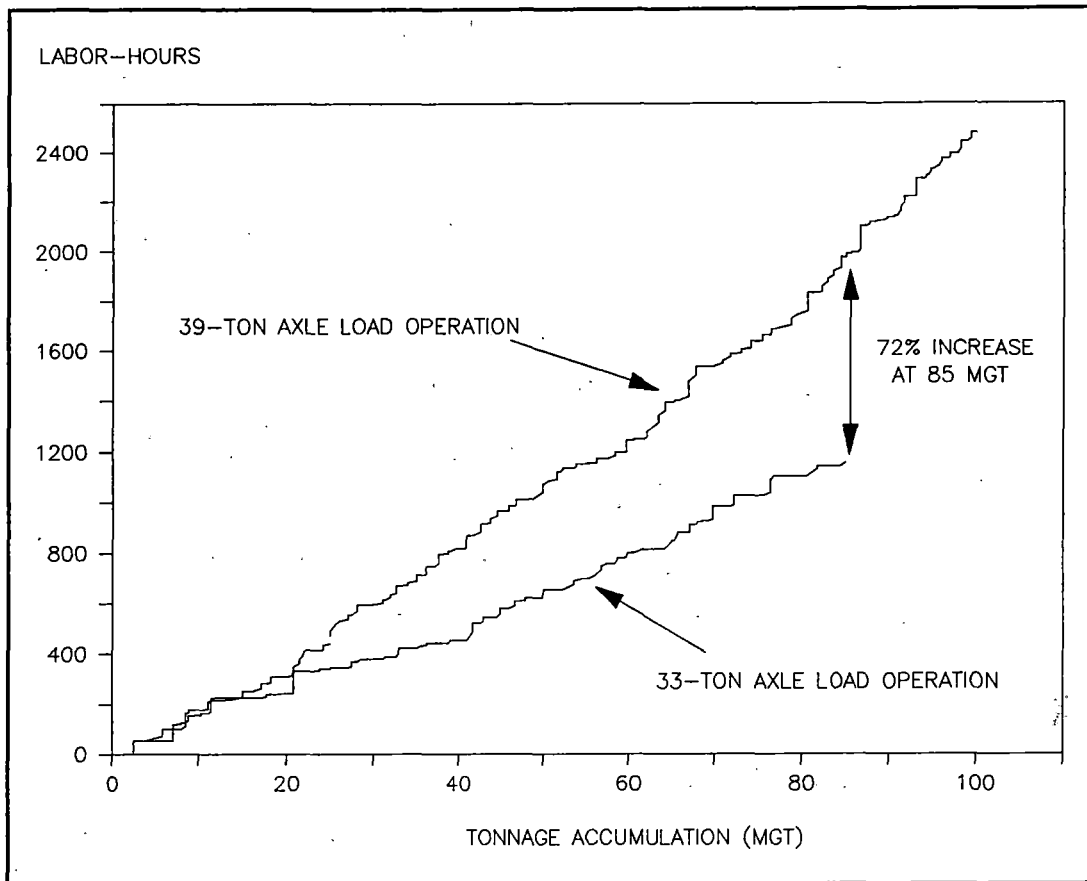


Figure 16. Track Maintenance Effort as a Function of Tonnage

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

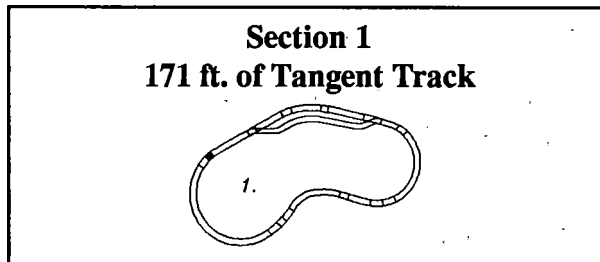
A CN profilometer is used to collect wheel profile data and a TTC snap gage measures wheel area loss.

Metallurgical Evaluation

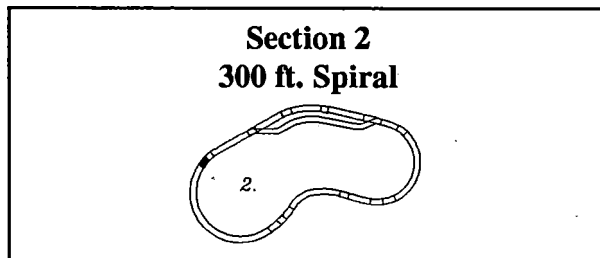
Selected rails and wheels exhibiting internal and/or surface defects are submitted to macroscopic inspection, metallography, hardness profiles, scanning electron microscopy and x-ray analysis.

DESCRIPTION OF HTL TRACK SECTIONS

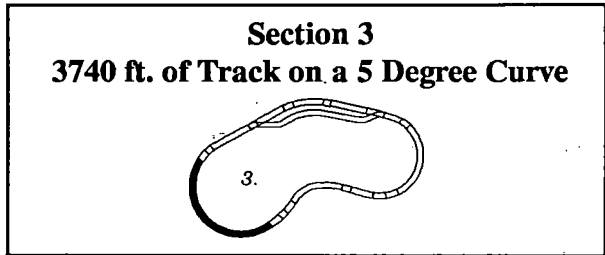
The typical HTL track structure consists of continuous welded rail fastened to wood ties with cut spikes and fully box anchored at every second tie. Included in specific test zones are concrete ties, jointed rail, and elastic type rail fasteners. A description of each section follows:



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



Transition zone/available for testing.

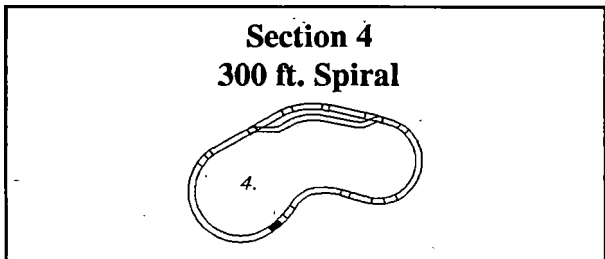


Location of Ballast, Rail Performance and Tie and Fastener Experiments.

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.

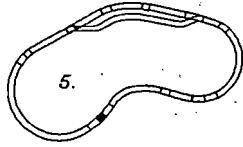
Tie measurements include track geometry, rail fastener stiffness, rail loads, dynamic rail deflection, tie plate cutting, and static track gage.

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



Transition zone/available for testing.

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



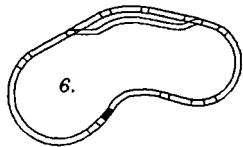
Location of Subgrade Experiment and Frog Casting Performance Test.

Measurements include static and dynamic subgrade pressure and deflection.

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

Location of hot bearing and acoustic bearing detector.

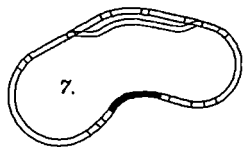
**Section 6
300 ft. Spiral**



Location of Ballast Resistance Characterization Test.

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

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

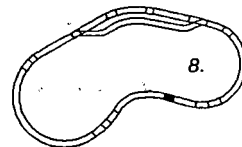


Location of Tie and Fastener and Rail Performance Experiments.

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

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

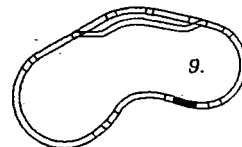
**Section 8
300 ft. Spiral**



Location of Ballast Resistance Characterization Experiment.

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

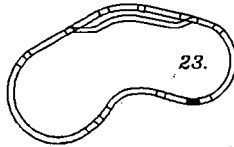
**Section 9
313 ft. of Tangent Track**



Road crossing and #10 turnout.

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

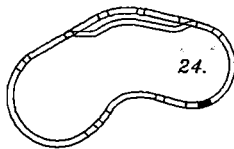
Section 23
164 ft. of Track on a 1 Degree-45 Minute
Curve
and
201 ft. of Tangent Track



Frog Casting Performance Test.

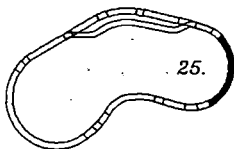
Wayside rail lubricator.

Section 24
300 Ft. Spiral



Transition zone/available for testing.

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

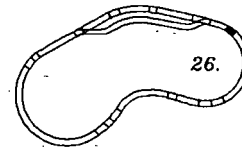


Location of Rail Performance, Ballast Resistance Characterization and Tie and Fastener Experiments.

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

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

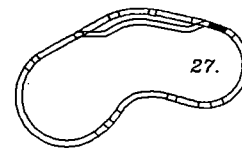
Section 26
300 ft. Spiral



Location of Tie and Fastener Experiment.

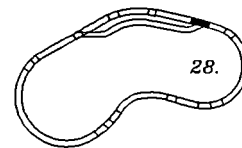
Measurements include static gage widening.

Section 27
332 ft. of Tangent Track



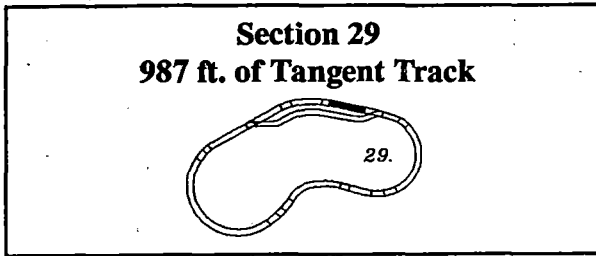
Location of Frog Casting Performance test.

Section 28
#20 Left Hand Turnout



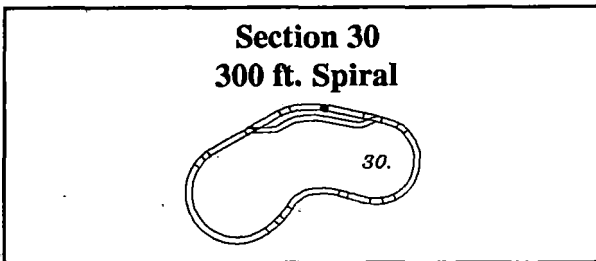
Location of Turnout Experiment.

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

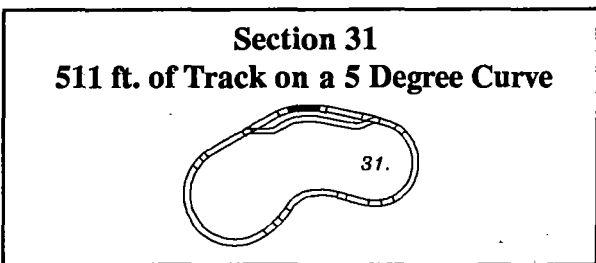


Location of Track Irregularity Experiment

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

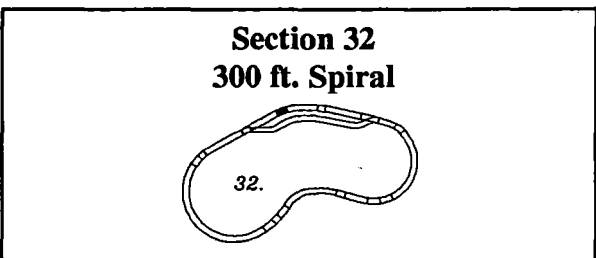


Transition zone/available for testing.

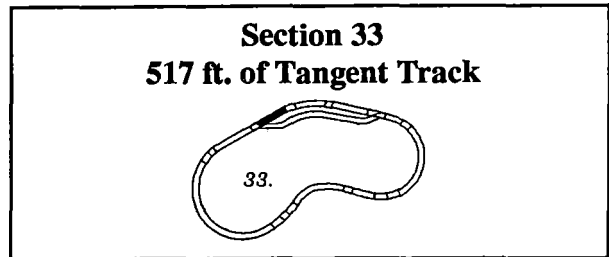


Location of Tie and Fastener Test.

Measurements include tie plate cutting and track geometry.

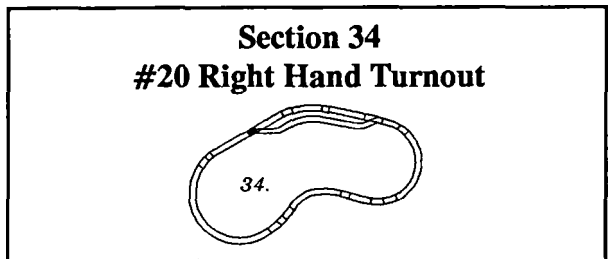


Transition zone/available for testing.



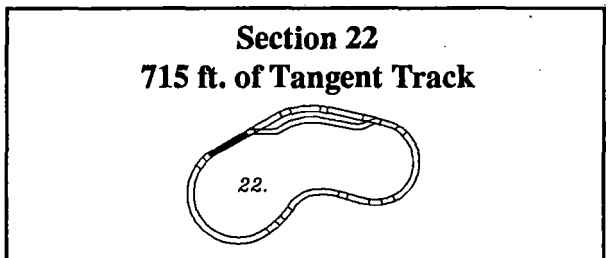
Location of Ballast Resistance Characterization Experiment and Frog Casting Performance Test.

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



Location of Turnout Experiment.

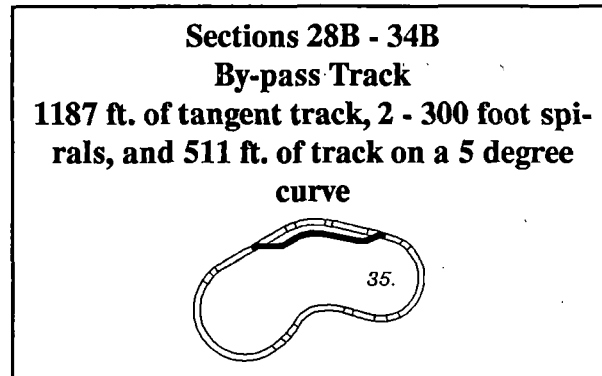
Measurements include rail/wheel loads, dynamic rail deflections, lateral and vertical rail stiffness, and track geometry.



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.



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.

APPENDIX C
SNAP GAGE DATA

The Snap Gage readings, in inches, for each car and wheel are provided in the following tables.

FLANGE WIDTH MEASUREMENTS - R1 WHEELS

DATE	10/03/88	10/21/88	11/03/88	11/10/88	03/27/89	05/24/89	10/04/89	01/09/90	03/13/90	05/23/90
MILES	0.00	992.80	1934.00	2624.80	5002.10	11320.66	15578.27	19120.80	24835.59	28998.00
132	0.592	0.530	0.490	0.492	0.480	0.440	0.439	0.435	0.420	0.414
137	0.677	0.576	0.485	0.481	0.483	0.451	0.445	0.430	0.404	0.399
165	0.654	0.603	0.593	0.598	0.592	0.578	0.550	0.545	0.522	0.523
305	0.616	0.523	0.465	0.458	0.453	0.426	0.398	0.384	0.350	0.340
349	0.604	0.549	0.490	0.483	0.463	0.452	0.410	0.400	0.390	0.380

FLANGE WIDTH MEASUREMENTS - L1 WHEELS

DATE	10/03/88	10/21/88	11/03/88	11/10/88	03/27/89	05/24/89	10/04/89	01/09/90	03/15/90	05/23/90
MILES	0.00	992.80	1934.00	2624.80	5002.10	11320.66	15578.27	19120.80	24835.59	28998.00
132	0.598	0.547	0.494	0.487	0.467	0.468	0.459	0.455	0.453	0.447
137	0.686	0.576	0.508	0.490	0.477	0.449	0.428	0.410	0.409	0.414
165	0.610	0.567	0.514	0.510	0.490	0.483	0.444	0.439	0.437	0.436
305	0.614	0.536	0.480	0.475	0.466	0.457	0.338	0.425	0.423	0.420
349	0.602	0.500	0.428	0.425	0.425	0.424	0.378	0.366	0.366	0.368

FLANGE WIDTH MEASUREMENTS - R3 WHEELS

DATE	10/03/88	10/21/88	11/03/88	11/10/88	03/27/89	05/24/89	10/04/89	01/09/90	03/15/90	05/23/90
MILES	0.00	992.80	1934.00	2624.80	5002.10	11320.66	15578.27	19120.80	24835.59	28998.00
132	0.680	0.530	0.444	0.422	0.404	0.321	0.262	0.257	0.215	0.206
137	0.702	0.558	0.482	0.458	0.460	0.438	0.420	0.416	0.416	0.414
165	0.590	0.545	0.512	0.515	0.503	0.485	0.472	0.471	0.451	0.450
305	0.604	0.538	0.465	0.485	0.466	0.446	0.449	0.443	0.430	0.412
349	0.630	0.565	0.527	0.524	0.529	0.511	0.504	0.482	0.481	0.475

FLANGE WIDTH MEASUREMENTS - L3 WHEELS

DATE	10/03/88	10/21/88	11/03/88	11/10/88	03/27/89	05/24/89	10/04/89	01/09/90	03/15/90	05/23/90
MILES	0.00	992.80	1934.00	2624.80	5002.10	11320.66	15578.27	19120.80	24835.59	28997.00
132	0.693	0.594	0.502	0.482	0.460	0.437	0.405	0.400	0.400	0.400
137	0.696	0.601	0.518	0.516	0.478	0.442	0.400	0.391	0.380	0.370
165	0.566	0.510	0.462	0.450	0.431	0.409	0.387	0.370	0.370	0.370
305	0.612	0.505	0.457	0.442	0.435	0.329	0.390	0.370	0.367	0.362
349	0.611	0.590	0.425	0.410	0.393	0.357	0.288	0.298	0.292	0.290

RIM THICKNESS MEASUREMENTS - R1 WHEELS

DATE	10/03/88	10/21/88	11/03/88	11/10/88	03/27/89	05/24/89	10/04/89	01/09/90	03/15/90	05/23/90
MILES	0.00	992.80	1934.00	2624.80	5002.10	11320.66	15578.27	19120.80	24835.59	28998.00
132	0.638	0.634	0.647	0.669	0.657	0.652	0.694	0.699	0.706	0.714
137	1.124	1.149	1.146	1.162	1.197	1.221	1.266	1.270	1.291	1.298
165	1.132	1.143	1.156	1.172	1.178	1.206	1.217	1.234	1.243	1.251
305	0.657	0.686	0.695	0.703	0.721	0.746	0.776	0.779	0.787	0.802
349	0.630	0.654	0.672	0.685	0.711	0.738	0.771	0.775	0.800	0.815

RIM THICKNESS MEASUREMENTS - L1 WHEELS

DATE	10/03/88	10/21/88	11/03/88	11/10/88	03/27/89	05/24/89	10/04/89	01/09/90	03/15/90	05/23/90
MILES	0.00	992.80	1934.00	2624.80	5002.10	11320.66	15578.27	19120.80	24835.59	28998.00
132	0.531	0.538	0.578	0.593	0.597	0.522	0.578	0.675	0.671	0.671
137	1.149	1.180	1.208	1.208	1.211	1.208	1.215	1.203	1.225	1.231
165	1.106	1.125	1.130	1.143	1.137	1.150	1.152	1.156	1.160	1.159
305	0.659	0.699	0.707	0.722	0.723	0.733	0.735	0.746	0.753	0.755
349	0.653	0.677	0.694	0.678	0.708	0.710	0.732	0.737	0.743	0.742

RIM THICKNESS MEASUREMENTS - R3 WHEELS

DATE	10/03/88	10/21/88	11/03/88	11/10/88	03/27/89	05/24/89	10/04/89	01/09/90	03/15/90	05/23/90
MILES	0.00	992.80	1934.00	2624.80	5002.10	11320.66	15578.27	19120.80	24835.59	28998.00
132	1.155	1.176	1.182	1.186	1.219	1.248	1.262	1.281	1.300	1.311
137	1.160	1.172	1.192	1.203	1.212	1.245	1.264	1.283	1.306	1.325
165	0.604	0.609	0.614	0.618	0.622	0.639	0.652	0.664	0.661	0.673
305	0.639	0.649	0.672	0.684	0.714	0.744	0.788	0.799	0.826	0.818
349	0.660	0.683	0.705	0.709	0.762	0.784	0.853	0.835	0.858	0.864

RIM THICKNESS MEASUREMENTS - L3 WHEELS

DATE	10/03/88	10/21/88	11/03/88	11/10/88	03/27/89	05/24/89	10/04/89	01/09/90	03/15/90	05/23/90
MILES	0.00	992.80	1934.00	2624.80	5002.10	11320.66	15578.27	19120.80	24835.59	28998.00
132	1.120	1.153	1.162	1.152	1.175	1.186	1.188	1.204	1.215	1.221
137	1.145	1.177	1.184	1.208	1.203	1.225	1.210	1.218	1.222	1.244
165	0.588	0.613	0.613	0.629	0.625	0.616	0.627	0.643	0.646	0.653
305	0.662	0.680	0.696	0.682	0.719	0.725	0.740	0.741	0.753	0.753
349				0.673	0.688	0.699	0.708	0.835	0.736	0.741

APPENDIX D
BRINELL HARDNESS DATA

The Brinell hardness readings for each car and wheel are provided in the following tables.

CAR - 132		
WHEEL	BRINELL HARDNESS	
	POINT 1	POINT 2
R-1	351	351
L-1	332	343
R-3	340	345
L-3	361	363

CAR - 137		
WHEEL	BRINELL HARDNESS	
	POINT 1	POINT 2
R-1	361	353
L-1	361	351
R-3	361	340
L-3	351	340

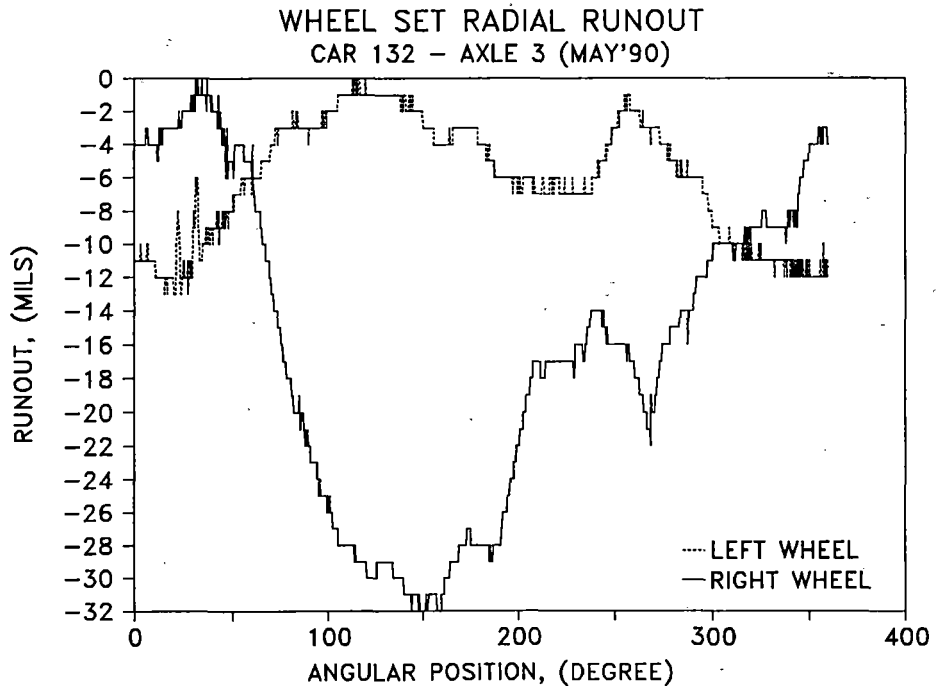
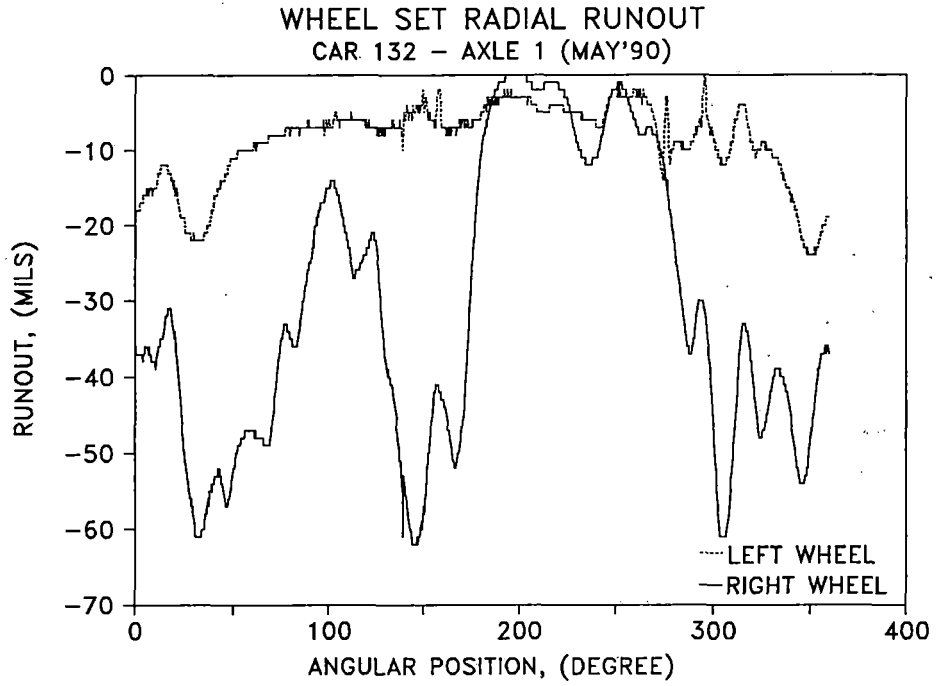
CAR - 165		
WHEEL	BRINELL HARDNESS	
	POINT 1	POINT 2
R-1	340	340
L-1	340	351
R-3	361	360
L-3	340	340

CAR - 305		
WHEEL	BRINELL HARDNESS	
	POINT 1	POINT 2
R-1	360	361
L-1	358	361
R-3	359	361
L-3	361	358

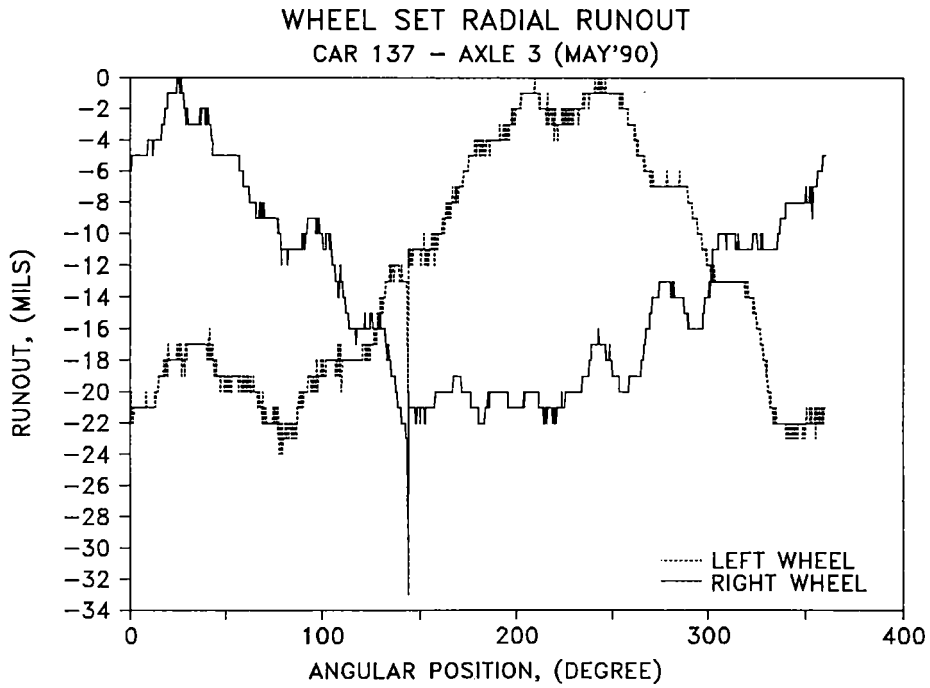
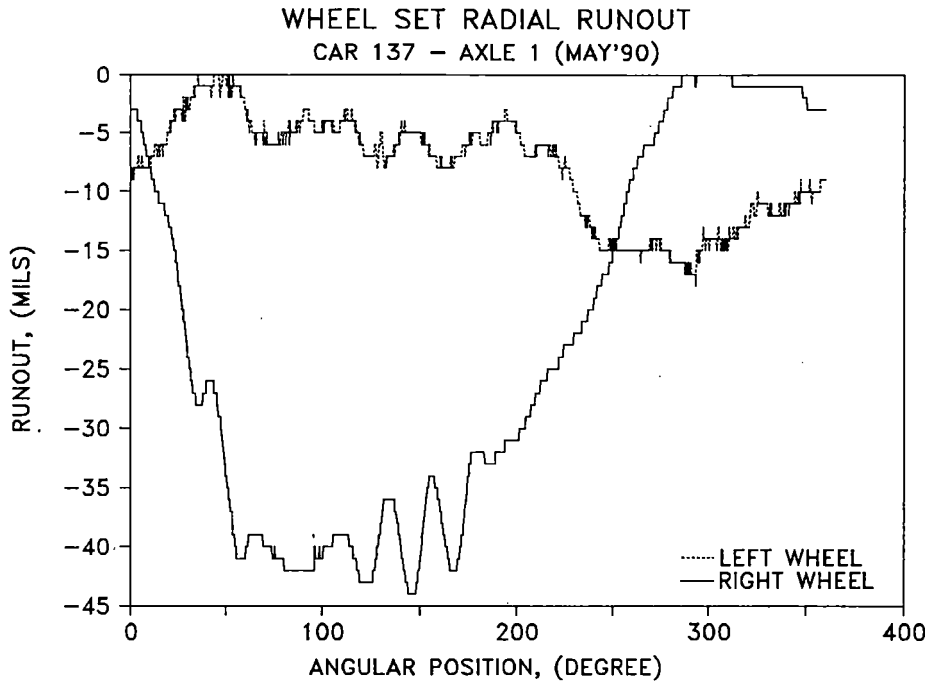
CAR - 349		
WHEEL	BRINELL HARDNESS	
	POINT 1	POINT 2
R-1	360	362
L-1	360	358
R-3	360	358
L-3	361	360

APPENDIX E
LONGITUDINAL WHEEL PROFILE DATA

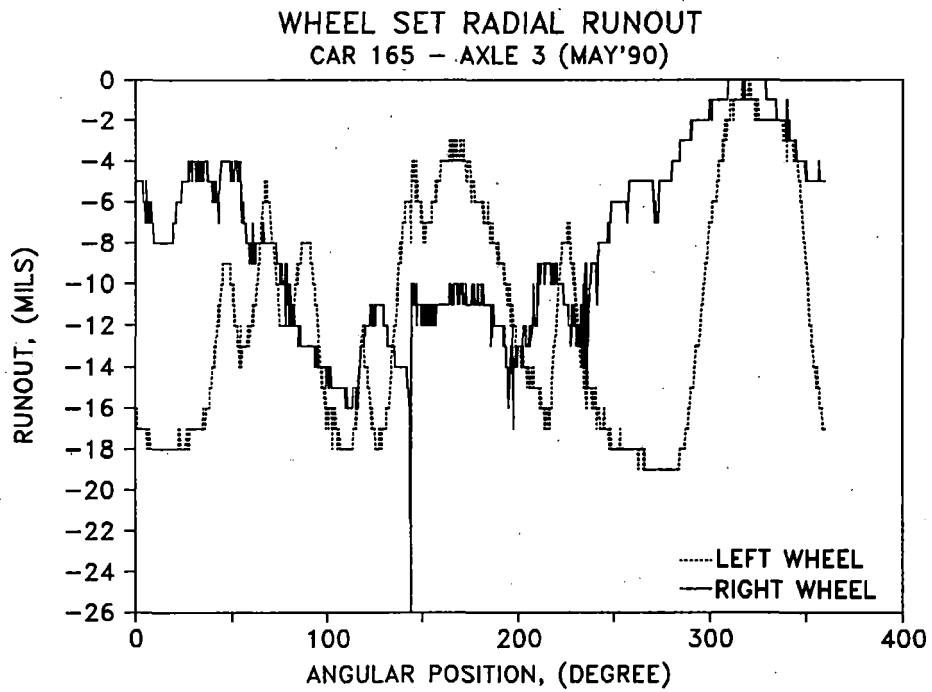
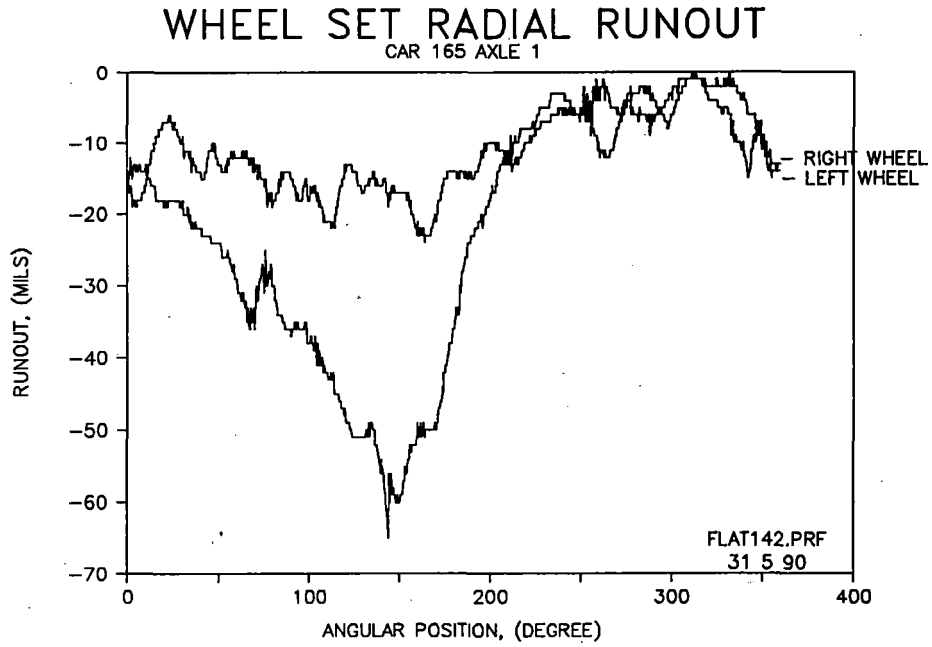
Longitudinal Wheel Profile Data - Car 132



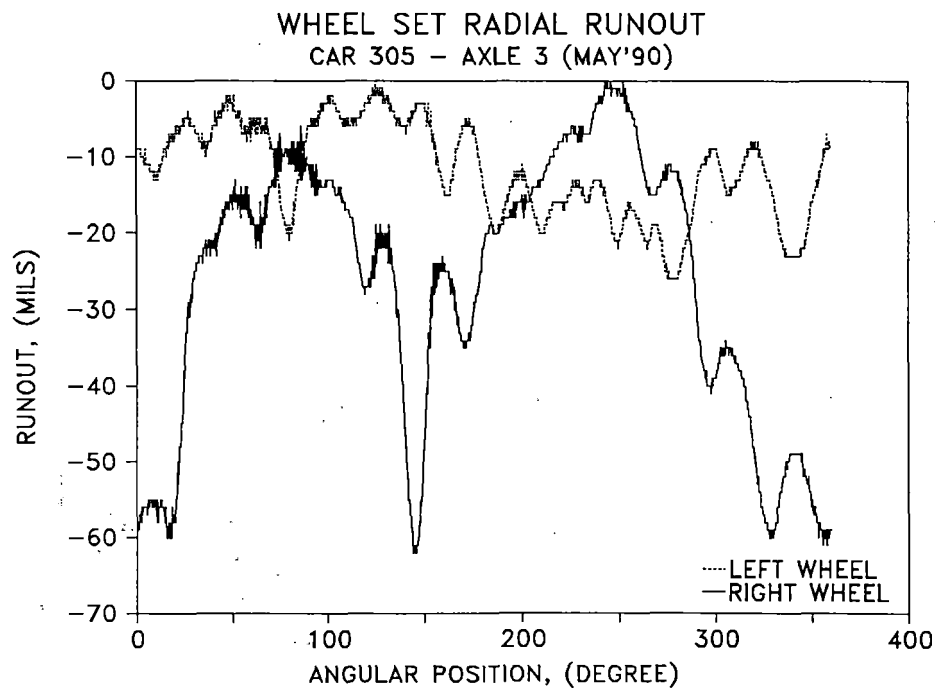
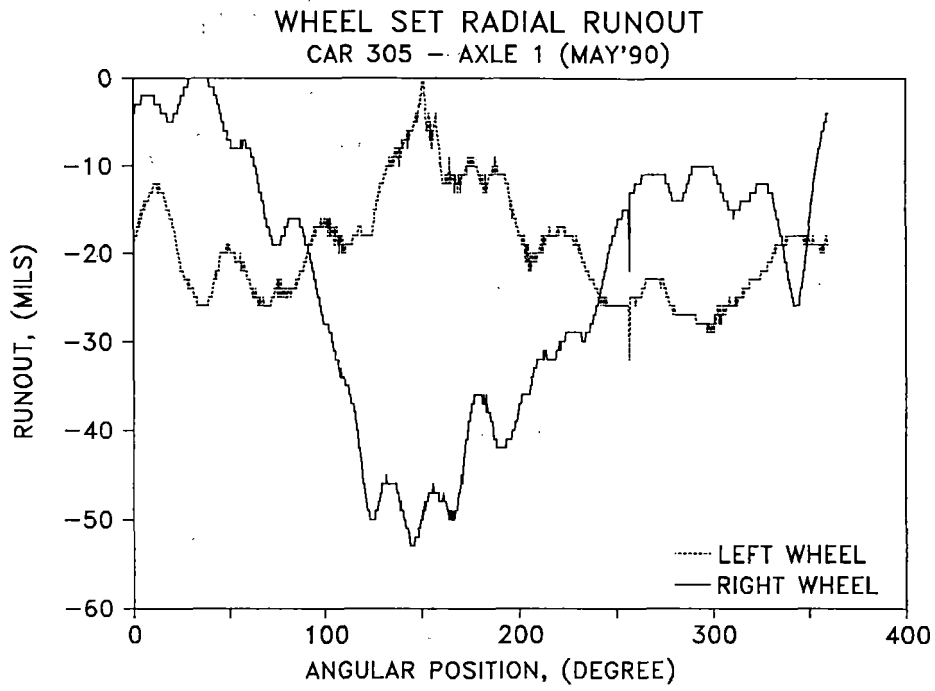
Longitudinal Wheel Profile Data - Car 137



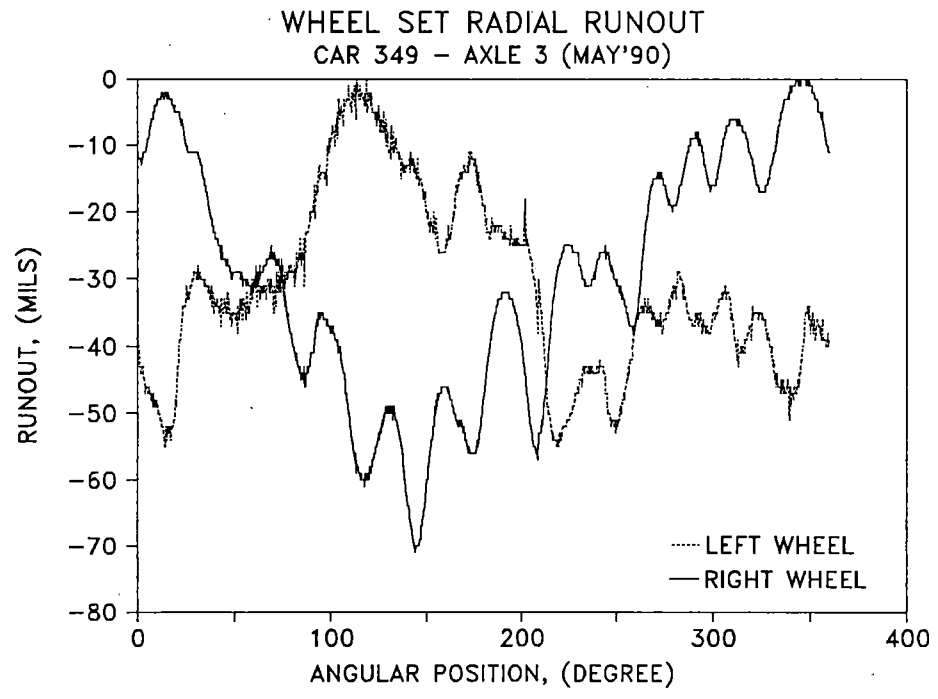
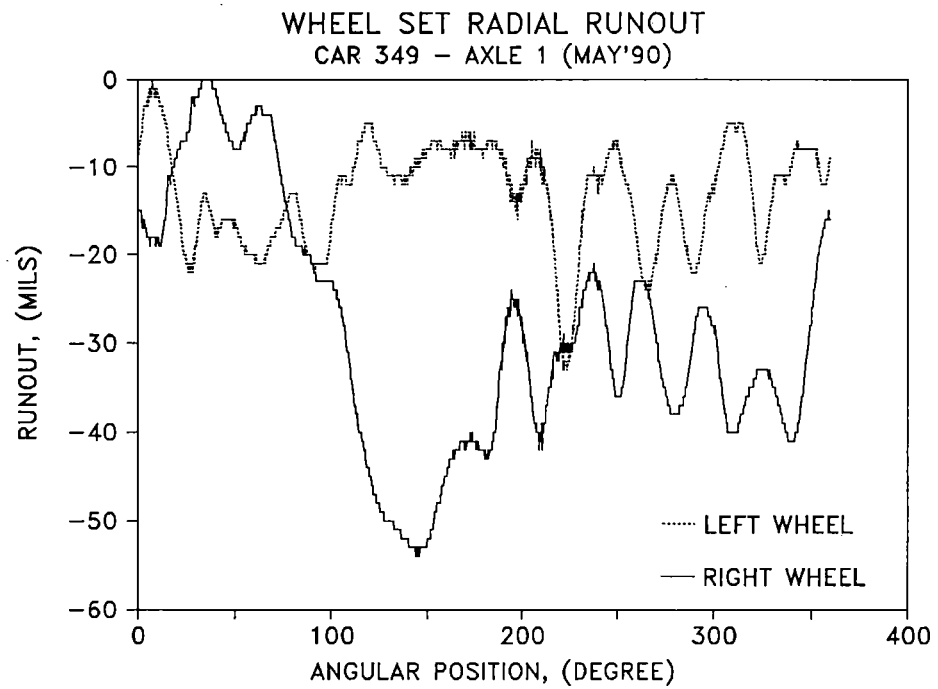
Longitudinal Wheel Profile Data - Car 165



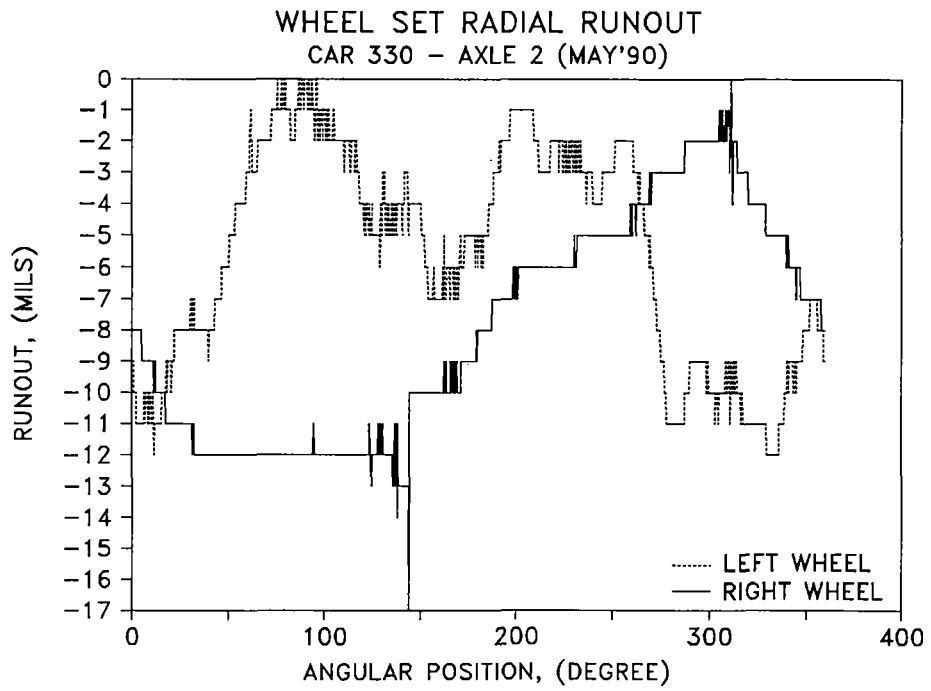
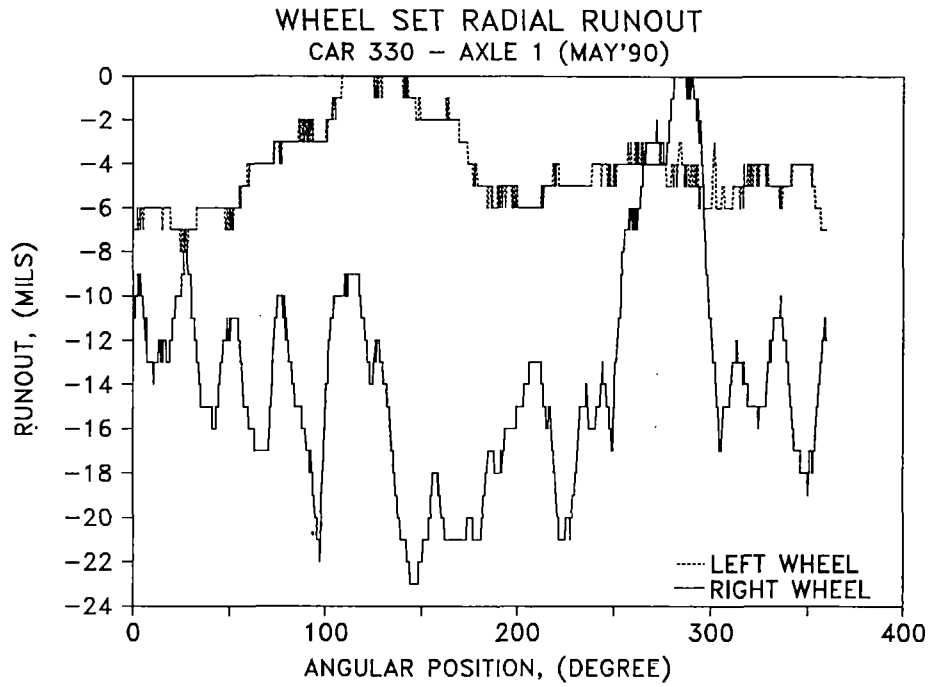
Longitudinal Wheel Profile Data - Car 305



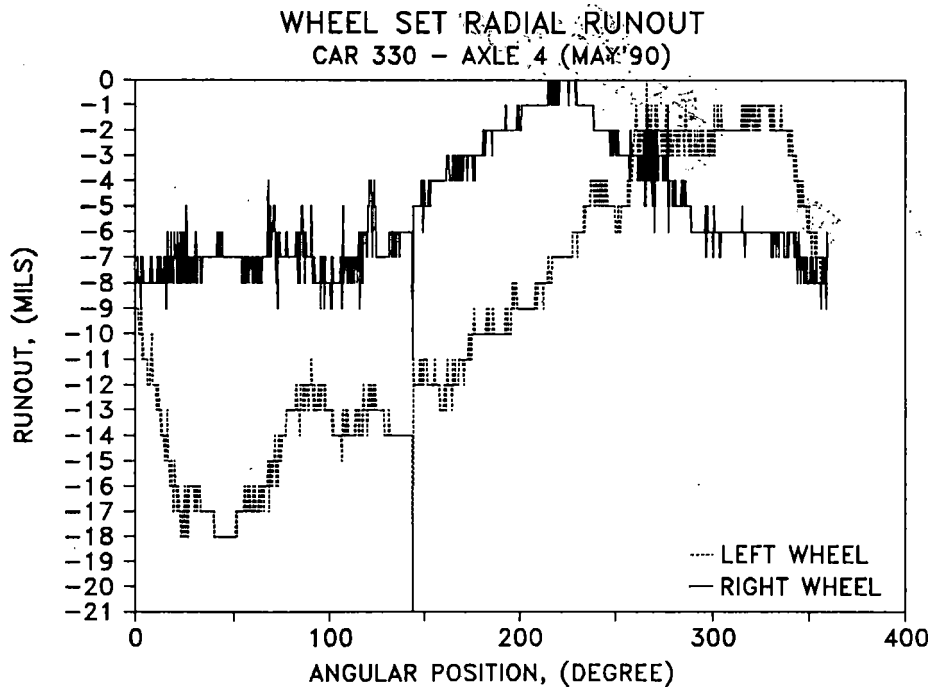
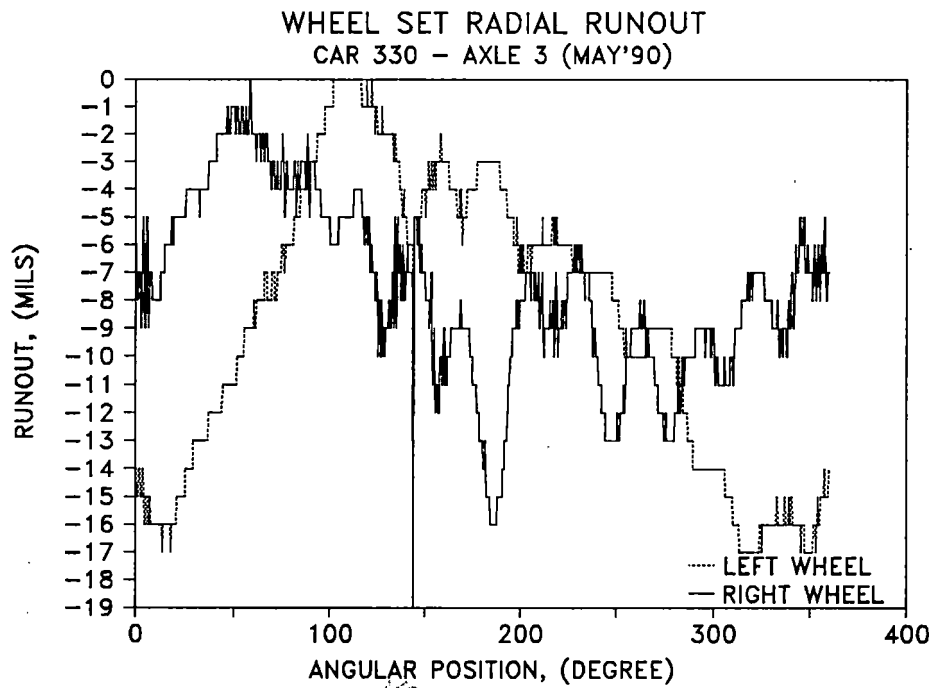
Longitudinal Wheel Profile Data - Car 349



Longitudinal Wheel Profile Data - Car 330



Longitudinal Wheel Profile Data - Car 330



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FAST/HAL Mechanical Components Performance Test,
AAR Report R-787, 1991, Association of American
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