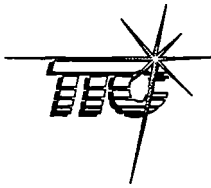


# **“ Introduction of HALTraffic (286 Cars) on Revenue Service Lines: A Preliminary Analysis,”**

**by M. Carmen Trevizo, John D. Mazza,  
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## **Summary**

Preliminary results of the Association of American Railroad's (AAR) Heavy Axle Load (HAL) Revenue Service Monitoring Program suggest that the effects of HAL traffic on revenue service lines are very similar to those experienced on the High Tonnage Loop (HTL) at the Transportation Technology Center (TTC), Pueblo, Colorado. The AAR's goal is to monitor the degradation of track and track components in revenue service and/or in environments not found on the HTL at TTC's Facility for Accelerated Service Testing (FAST). This will allow the AAR to detect and advise the industry of HAL traffic related findings not seen at FAST.

A variety of tests are being conducted in selected revenue service lines to address the following areas of concern: concrete tie performance, performance of wheels and bearings, bridge performance, turnout and component performance, wood tie degradation, and track degradation on a low modulus subgrade.

Data collected yielded the following results:

- Wheel load data sampled in 1995 on the Chicago and North Western (CNW) Powder River Subdivision and CSX Transportation (CSXT) Coal River Subdivision showed that about 13 percent of the loaded unit trains on the CNW and 10 percent on the CSXT had an average car weight per train above 286 kip. Wheel loads are being measured to monitor HAL traffic and to correlate with measured degradation rates.
- Concrete tie measurements at the rail seat area show that tie bending strains are relatively low. However, the increase in bending strains at the tie center is evident with the increase in axle loads. The increase in tie center bending strains due to the increase in axle load on the HTL (39-ton) ranged from 15 to 35 percent, while the increase in center bending strains in revenue service (36-ton) ranged from 20 to 40 percent. Lateral loads appear to have a big influence on the tie center bending strains.
- No tie degradation was measured during the three years that the Norfolk Southern wood tie test site was monitored. Lateral wheel loads measured on this 5.1-degree curve are comparable or less than those measured on a comparable curvature on the HTL track. There was very little difference in gage strength between 1993 and 1995 measurements. Because track was well maintained in this area by plugging and re-spiking any high spikes, nominal track gage degradation was measured.
- The CNW Powder River Subdivision is using premium quality Nos. 10 and No. 20 frogs to achieve longer frog life.

## INTRODUCTION AND CONCLUSIONS

The Association of American Railroads (AAR) Heavy Axle Load (HAL) Revenue Service Monitoring Program is evaluating the introduction of HAL traffic (286 kip cars) on revenue service lines. The program was initiated in 1992 with the primary goal of monitoring track environments not found in the High Tonnage Loop (HTL) at the Transportation Technology Center's (TTC) Facility for Accelerated Service Testing (FAST).

A variety of tests are being conducted in selected revenue service lines to address the following areas of concern: concrete and wood tie performance, performance of wheels and bearings, bridge performance, turnout and component performance, and track degradation on a low modulus subgrade. Wheel loads are also being measured to monitor the rate at which HAL traffic is introduced and to correlate with measured degradation rates.

## LOAD MONITORING

To quantify the loads over the line as HAL traffic is introduced, load monitoring stations have been installed on two different revenue service lines. One site located on a single track of the Chicago and North Western (CNW) Powder River Subdivision sees both loaded and empty coal trains. The second site located on a single track of the CSX Transportation (CSXT) Coal River Subdivision sees the same type of traffic. At each site, an automated load monitoring station collects continuous wheel load information on the passing trains.

The CNW Powder River Subdivision is almost exclusively unit coal trains. The loads, which make up about 80 percent of the tonnage, all move eastward, while the empties, which make up the remaining 20 percent of the tonnage, move westward. Track speed is 45 mph for loaded trains and typical train length is about 110 cars.

On the CSXT Coal River Subdivision, which is almost exclusively unit coal trains, the loads move in the northward direction and the track speed is 25 mph for loaded trains. Typical train length is about 200 cars.

## AVERAGE CAR WEIGHT

Figure 1 shows a histogram of the distribution of average car weight per train for coal trains sampled between April 1994 and May 1995 under normal operating conditions on the CNW. Because the histogram has a valley centered about 278 kips, this car weight was selected as a break point between conventional trains and HAL trains (i.e., all loads above 278 kips are considered to be from HAL cars). Note that the number of trains loaded to above 286 kips per car is significant.

The distinction between trains with average car weights of 263 kips and 286 kips is not as well defined as one might expect. It is likely that some trains of 286-kip cars are not being fully loaded, and/or that some trains of 263-kip cars are being overloaded. Either of these practices could contribute to the significant number of trains loaded at intermediate levels.

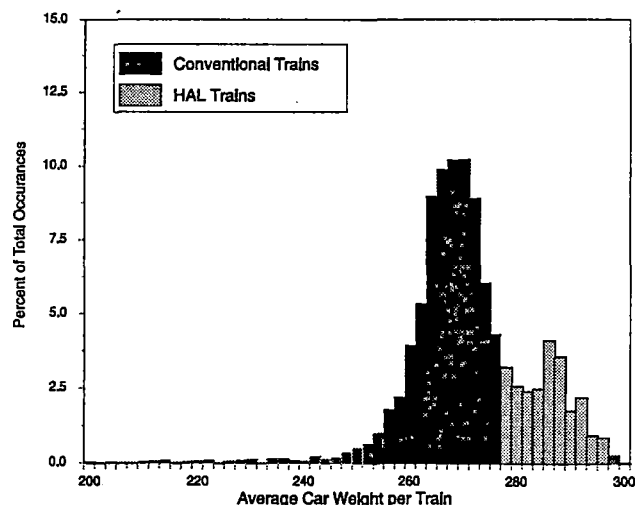
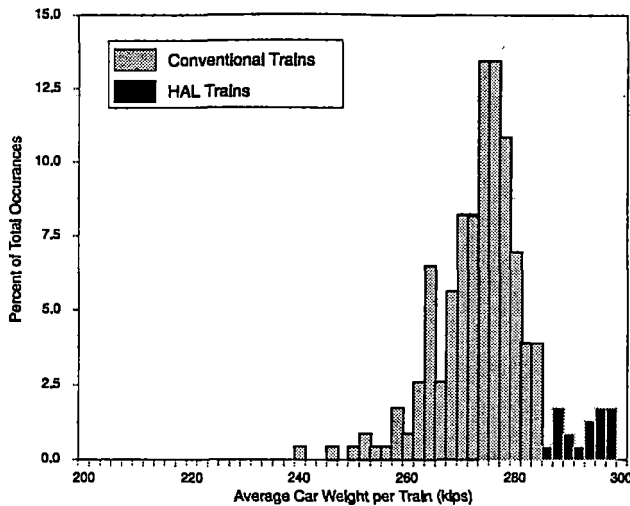


Figure 1. Histogram of Average Car Weight per Train on the CNW

Figure 2 shows a histogram of the distribution of average car weight per train for coal trains sampled between April and May 1995 under typical operating conditions on the CSXT. The break point for conventional and HAL cars is different on the CSXT line than that measured on the CNW (278 kips). Data shown in Figure 2 suggests that there are either a number of overloaded conventional cars or under loaded HAL cars. The break

point for the HAL cars for this line is approximately 286 kips.



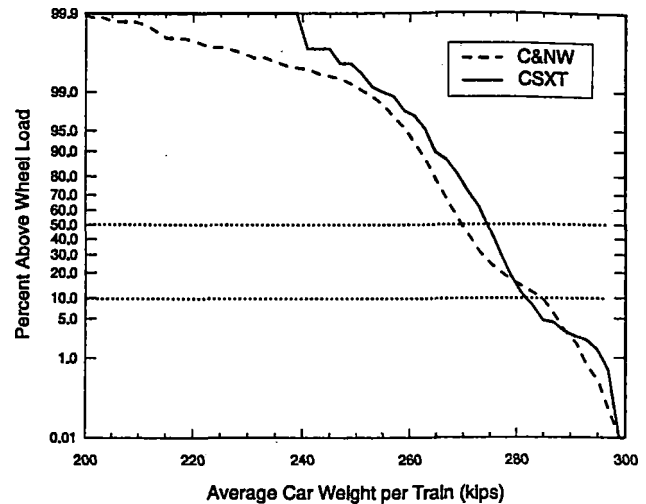
**Figure 2. Histogram of Average Car Weight per Train on the CSXT**

Depending on train handling, a road crossing located near the approach of the CSXT load station can significantly affect car dynamics, thus influencing the measured vertical wheel loads. To eliminate the car dynamics variable from the data, additional instrumentation was installed in an area where car dynamics were minimal. The data shown on the graph includes only the data collected after the additional instrumentation was installed.

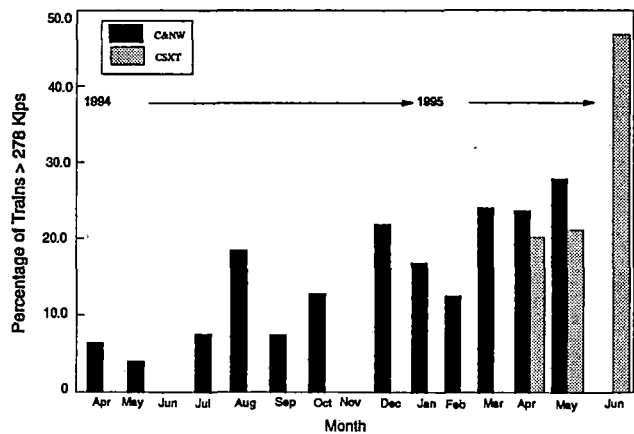
Figure 3 shows a cumulative distribution of average car weights per train for the same data shown in Figures 1 and 2. On the CNW, 90 percent of the trains have an average car weight per train above 263 kips; 13 percent have an average car weight above 286 kips. While on the CSXT, about 94 percent of the trains have an average car weight per train above 263 kips; and about 10 percent have an average car weight above 286 kips. The highest observed average car weight for one train was nearly 300 kips.

Figure 4 shows the percentage of all HAL trains with gross rail loadings above 278 kips for both lines. The fluctuations in monthly percentages may be due to a variety of fac-

tors, such as train cycle times, policy changes, operating conditions, and mine loading practices. The rate at which HAL cars are introduced into revenue service continues to increase with time.



**Figure 3. Distribution of Average Car Weight per Train on the CNW and CSXT**

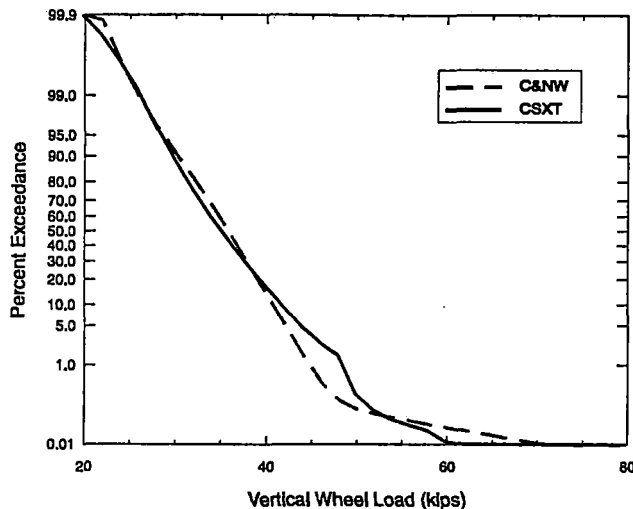


**Figure 4. Percent of Trains Exceeding 278 Kips on the CNW and CSXT**

## AVERAGE WHEEL LOADS

Figure 5 shows the cumulative distributions of wheel loads measured for HAL trains for both the CNW and the CSXT. Mean wheel loads for the measured HAL trains on the CNW was 36 kips and 35 kips on the CSXT. Ten percent of the wheel loads on the CNW exceeded 45 kips, and 10 percent of wheel loads exceeded 48 kips on the CSXT.

While the highest measured vertical wheel load on the HAL trains for the CNW was 85 kips and 66.7 kips on the CSXT, the highest measured vertical wheel load on the conventional trains was 73 kips on the CNW and 60.2 kips on the CSXT. These high values were probably generated by wheel impacts. The highest measured lateral loads on the CSXT for HAL trains was 29.4 kips, and 24.3 kips for the conventional trains.



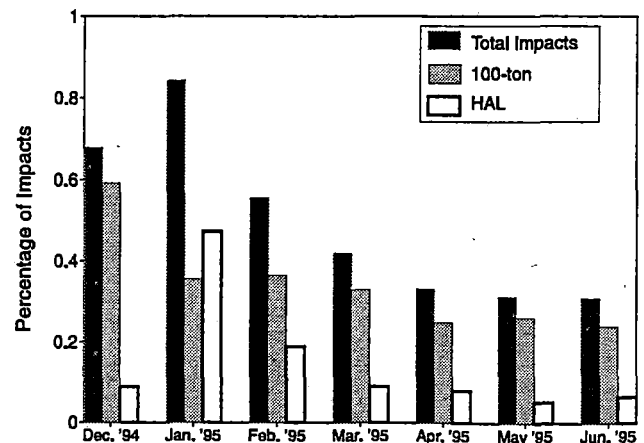
**Figure 5. Vertical Wheel Load Distribution for Loaded Cars on the CNW**

The static wheel load of a HAL 286-kip car is 35.7 kips. Considerable variations in wheel loads in both load station sites are most likely due to uneven loading, as well as car dynamics through the measurement zone. Table 1 provides a summary of vertical and lateral wheel load statistics. Note that the CNW load station is located on a typical curve for this line, a 1.5-degree curve; therefore, the lateral wheel loads are very low. Because the load station is located on an 8.4-degree curve, lateral wheel loads on the CSXT are much higher.

**Table 1. Lateral and Vertical Wheel Load Statistics**

Mean (kips)	100-Ton Cars	HAL Cars
Vertical Wheel Loads		
CNW	33.0	35.5
CSXT	33.1	35.6
Lateral Wheel Loads		
CNW	1.3	1.0
CSXT	6.1	7.9

The load station on the CNW was modified, additional vertical track circuits were installed and the lateral circuits removed. Only the vertical loads were measured since the measured lateral loads were so low. The new setup, which includes seven consecutive cribs instrumented with vertical rail circuits, provides about 65 percent coverage of the wheel circumference and allows for the capture of impact loads. Figure 6 shows the measured impacts loads on the CNW during the last 6 months.



**Figure 6. Percentage of Measured Impacts on the CNW above 60 kips**

## CONCRETE TIES

Concrete tie bending strain data is being collected on two lines to monitor tie performance under HAL traffic. The data is collected over 3 or 4 days once a year on the CSXT's James River Subdivision near Eagle Rock, Virginia, and on the BN's Spanish Peaks Subdivision near Mayne, Colorado. Tie bending strains are measured on two tie designs on the CSXT line and on a single tie design at the BN test site for comparison of several types of ties.

Data collected at both sites in 1993 and 1994 only captured conventional 100-ton traffic. But in March 1995, data was collected on several HAL trains at the CSXT site. The 6.1-degree curve has a track speed of 40 mph. Figure 7 shows the distribution of tie center bending strains, comparing a HAL train to a conventional train collected at this time. A bimodal distribution of the data is evident in the graph. While the high strain segment reflects the peak strains generated by a pair of coupled trucks, the low strain segment reflects the peak strains of the four individual axles. There is a noticeable increase in the bending strain magnitudes with the HAL train which may lead to a decrease in tie life.

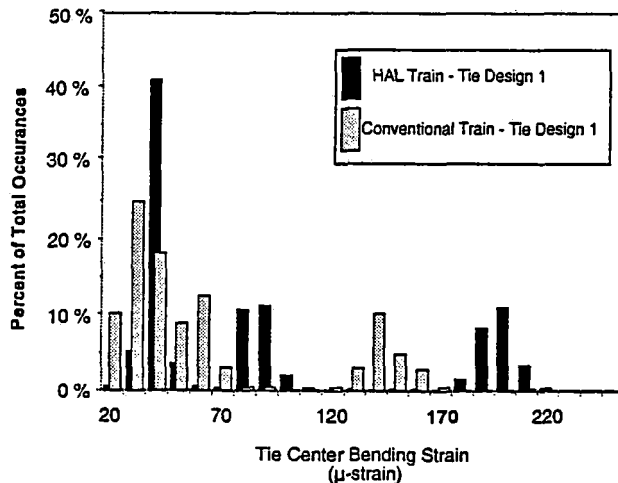


Figure 7. Histogram of Concrete Tie Center Bending Strains on the CSXT

Because the tie bending strains measured on the rail seat area are significantly less than those measured on the tie center, no significant differences were measured between conventional and HAL traffic on the rail seat area. Figure 8 shows the distribution of the concrete tie center bending strains under a conventional and HAL train at the concrete test site.

The median tie center bending strain measured under HAL trains is 60 microstrains, while 10 percent of center bending data measured exceeded 220 micro strains.

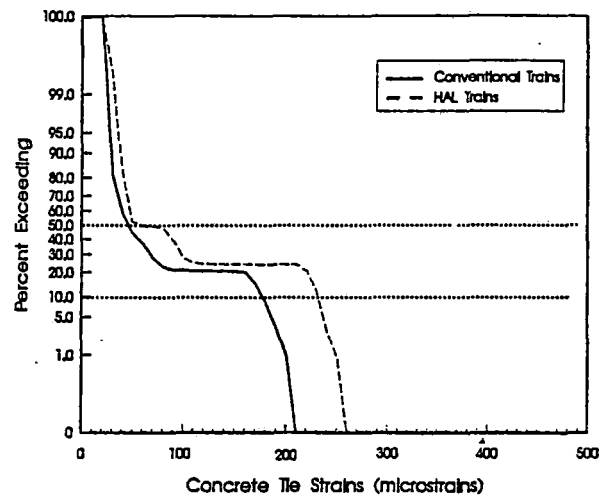


Figure 8. Distribution of Concrete Tie Center Bending Strains

In October, 1994, concrete tie strain gage instrumentation was added to the load station on the CSXT Coal River Subdivision near St. Albans, West Virginia. The curve is 8.4-degrees and has a track speed of 25 mph. The addition of this site allows continuous collection of concrete tie data, rather than the once-a-year collection performed on the two concrete test sites. A database of the measured concrete tie bending strain data on this site will allow for long-term monitoring of the tie performance as HAL traffic is increased. Figure 9 shows a slice of the time history for data collected under a HAL train at the load station site.

Lateral gage spreading forces influence tie center bending.<sup>1</sup> As much as 15 percent of the tie center strain measured at FAST can be attributed to gage spreading forces. Ties measured in revenue service and on the HTL were of different manufacturers but had a similar tie design. At a later date, gage spreading forces and center bending strains on this revenue site will be analyzed and reported.

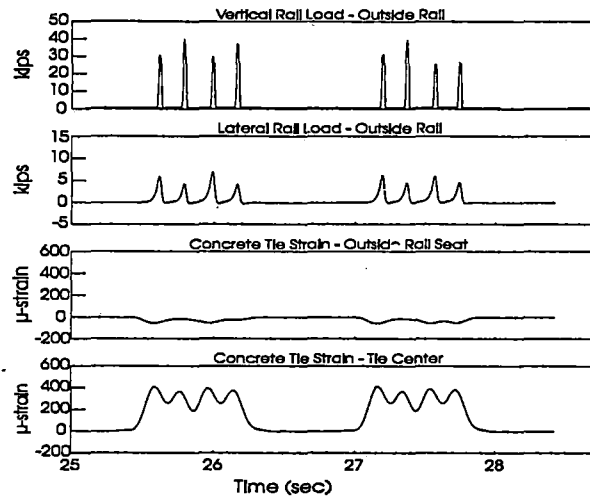


Figure 9. Time History of Data Collected at CSXT

## WOOD TIES

The objective of this experiment is to study the possible effects that introducing HAL traffic may have on track strength performance. This includes the lateral restraint capabilities of the typical spike-fastened wood ties in revenue service with varying curvature and climate environments.

The test curve chosen is located on the Norfolk Southern Roanoke-Bluefield line, which carries coal and mixed freight with an annual tonnage of about 140 million gross tons. The curve is constructed of mixed hardwood ties with cut spikes, has a 5.1-degree curvature and a 25 mph track speed. Track gage strength and dynamic rail load and deflections have been taken over the past three years. As a result of track maintenance performed in the summer of 1995, when rail,

selected ties, and the cut spike system were replaced, the curve is now equipped with the Pandrol fastening system.

Figure 10 shows very little difference between the unloaded and loaded track gage strength measured in 1993 and 1995. Because track was well maintained in this area by plugging and re-spiking any high spikes, nominal track gage degradation was measured.

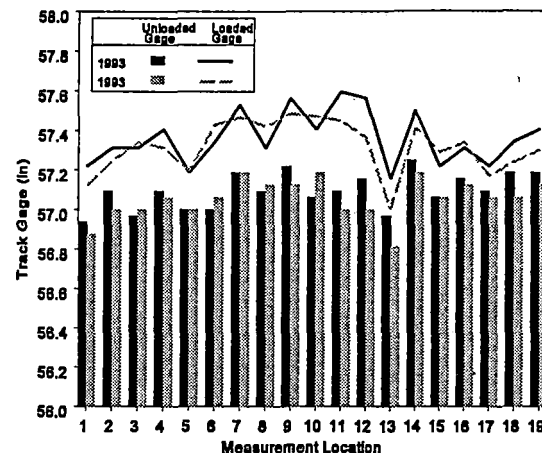
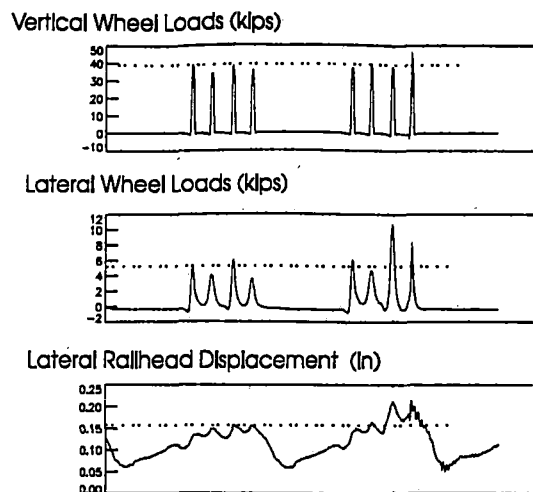


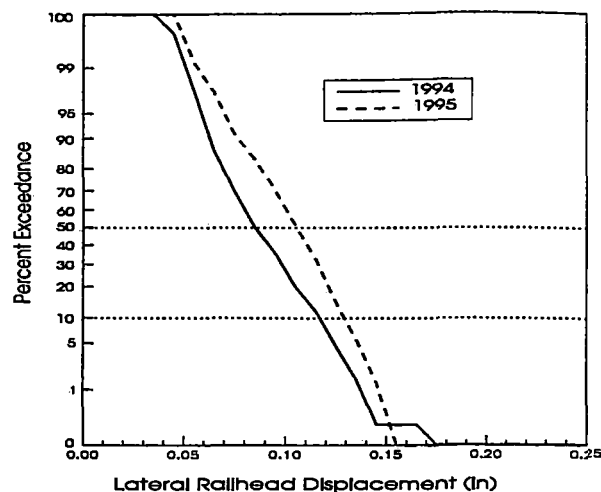
Figure 10. Track Gage Measurements on the NS

Figure 11 shows a time slice of the vertical, lateral and railhead displacement taken under a HAL train in 1995. There is an increase in lateral load magnitude from one truck to another, which may be due to a heavier car or skewed axles. This lateral load increase is also reflected in the increase of lateral railhead deflection. The increase in lateral loads and railhead displacement may influence tie life.

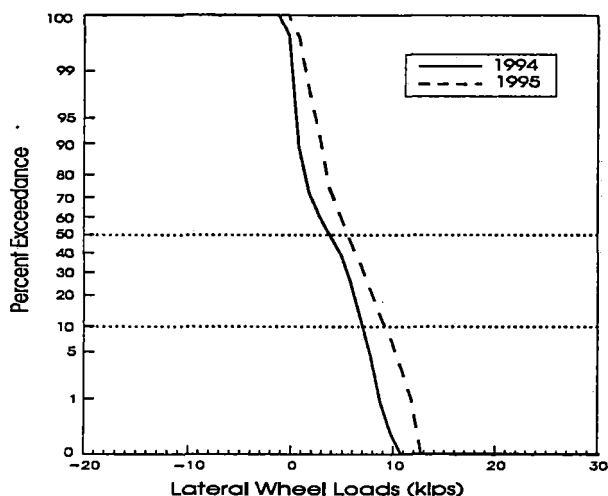
Figures 12 and 13 show the distribution of the lateral and railhead displacement measured on four trains in 1994 and 1995. The small difference between the two cycles in wheel lateral load and displacement may be due to the loading of the train, train speed, train handling or measurement error.



**Figure 11. Dynamic Data Collected under HAL Train on the NS**



**Figure 13. Distribution of Railhead Displacement on the NS**



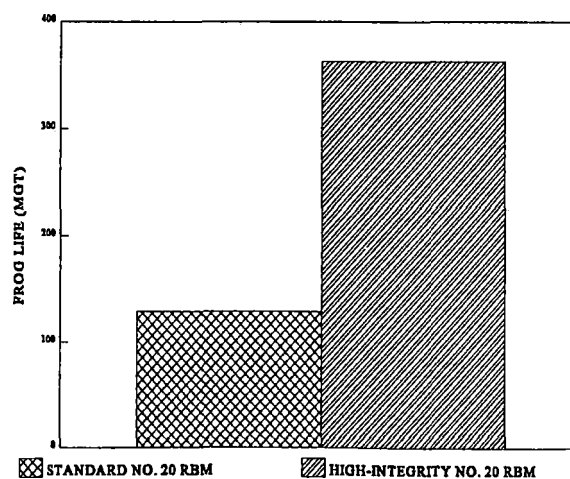
**Figure 12. Distribution of Wheel Lateral Loads on the NS**

## TURNOUTS

The Union Pacific Railroad (UP) is using premium quality No. 10 and No. 20 frogs to achieve longer frog life on the former Chicago and North Western (CNW) Powder River Subdivision. Results from maintenance data collected as part of the AAR's Heavy Axle Load Revenue Service Monitoring Program is presented below.<sup>2,3,4</sup>

## No. 20 Rail-Bound Manganese Frog Life

Figure 14 shows the average life in million gross tons (MGT) of standard and high-integrity No. 20 rail-bound manganese (RBM) frogs on this line. Many high-integrity frogs are still in service, so a Weibull analysis was used to account for tonnage still accumulating over those frogs. On the average, high-integrity No. 20 frogs are lasting almost three times longer than standard frogs.



**Figure 14. Average Life of Standard and High Integrity Frogs**

High-integrity frogs were first installed in 1990 on this line. The castings have thicker walls, more risers and less porosity as compared to standard frog castings. Premium rail is used for the wing rails in high-integrity frogs, as compared to standard rail in the standard frogs. Other factors such as improved maintenance practices and the use of heavier base plates with elastic fasteners may also contribute to this increased frog life.

Figure 15 shows that the orientation of a frog with respect to the direction of heaviest tonnage appears to make a small difference in the average life of No. 20 frogs. Tonnage is split about 80 percent in one direction, and 20 percent in the opposite direction on this heavy haul route. For both standard and high-integrity No. 20 RBM frogs, the average life for frogs in facing point turnouts is somewhat less than for frogs in trailing point turnouts, with respect to the heaviest tonnage direction. These figures are based on 40 standard frogs and 45 high-integrity frogs. Of the high-integrity frogs, only 11 have failed to date. As tonnage continues to accumulate and additional frogs fail, these figures may change.

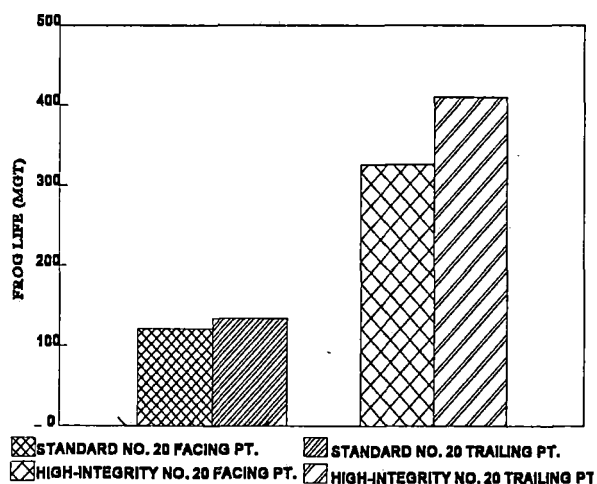


Figure 15. Average Frog Life - Facing and Trailing Point

As shown in Figure 16, two premium spring-rail frogs are lasting about eight and 11 times longer than the average life of standard No. 10 RBM frogs on this line. Both of these spring-rail frogs remain in service and continue to accumulate tonnage. These two frogs have seven wing rail hold-downs instead of three for a standard American Railway Engineering Association (AREA) design. They also have larger base plates and several braces ahead of the toe. They are protected by 39-foot guard rails on the mainline side instead of the 16.5-foot guard rail for a standard AREA design. The frogs are constructed of fully heat-treated rail and use a flexing wingrail (RT&S, March 1995, p. 29).

The fact that premium components, like the high-integrity No. 20 RBM frogs and the premium No. 10 spring-rail frogs, perform much better than standard components in heavy haul service complements the experience at the Facility for Accelerated Service Testing (FAST).

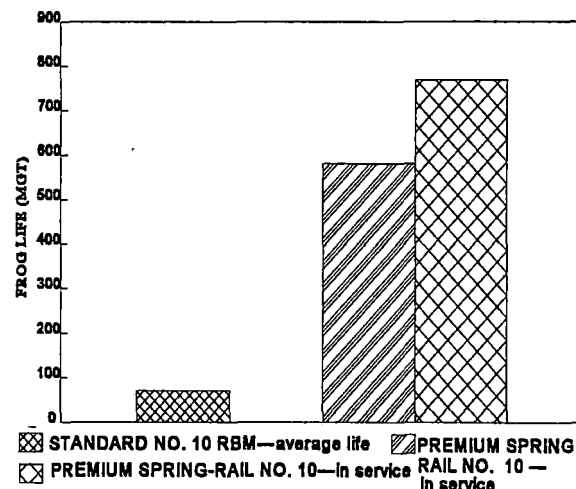


Figure 16. Life of No. 10 Frogs

Frog failures on this line are typically due to plastic flow, cracking, and spalling of the running surface. Frogs are removed from track when local maintenance forces judge them to be more economical to replace than repair by grinding and welding in the field. The welders keep maintenance records which provide some insight into the nature of the in-track repairs that are made during the life of a frog. On high tonnage lines such as this,



repairs are often done in intervals between trains. Thus, in-track repairs may create less train delay than frog replacement. When the deteriorated area becomes too large, the frog is replaced.

Because of the operating pattern on this line, the weld repairs occurred almost exclusively on the frog nose and the main wing. The side wing, used by diverging route moves, suffered little damage. The loaded trains usually hold the main line when two trains meet. Only empty trains use the diverging routes. The number of nose and wing repairs was about equal. Repair locations on the wing range from about 20 inches ahead of the tip of the frog nose to about 40 inches behind the tip, with the majority centered near the tip of the frog. Repairs on the frog nose ranged from the tip to about 40 inches towards the heel. Again, the majority were near the tip of the frog. Average repair lengths were about 15 inches on the wing and 19 inches on the nose of the frog.

The wide range of repair areas suggests that the lateral location of the wheel on the rail and frog is not fixed, nor is the lateral location of the contact area on the wheel. The effects of hollow tread or "false flange" wheels are present in this data. Comparison of the locations of consecutive repairs on the nose and main wing showed that repaired areas almost always overlap. Possible explanations include:

- Weld repairs are incomplete. Not all of the damaged material is replaced.
- The weld material is inferior to the original casting.
- The weld repair process damages the underlying material.
- While the repair locations vary from frog to frog, traffic on a given frog tends to damage the same areas, before and after repairs.

The effect of traffic direction on weld repair was investigated and found to be negligible. Standard No. 20 RBM frogs that

had loaded facing point moves behaved in the same manner as frogs with trailing point moves.

## **Traffic and Train Operations**

Frog performance can be quite different on lines with different traffic mixes, train speeds, operating practices, and maintenance procedures. It is important to know the conditions for the frog results presented here. Data has been collected over the past 12 years by the CNW on the Powder River Subdivision, between Horse Creek, Nebraska, and Shawnee Junction, Wyoming. Traffic is almost exclusively unit coal trains. While loads make up about 80 percent of the tonnage, all moving eastward, empties make up the remaining 20 percent, moving westward.

Speed limit on the line was originally 40 mph in each direction, but over the past four years it has been raised to 45 mph for loads and 50 mph for empties. At the time this data was last updated, the speed limit was being raised to 60 mph for both loads and empties. Speed is limited to 25 mph through the diverging routes of No. 20 turnouts.

As a general practice, loads hold the main track and empties take the siding when trains meet. Therefore, none of the No. 20s carry more than about 20 percent of the tonnage over the diverging route.

Traffic on this line was nearly all 100-ton cars with 33-ton axle loads until about 1992. Since then the amount of HAL traffic with 36-ton axle loads has gradually increased. It is estimated that about 20 to 25 percent of the traffic in 1995 will be HAL traffic.

Over the years, the CNW made several improvements in frog maintenance on this line, including installation of longer guard rails, frog gage plates, larger frog base plates, and elastic fasteners. Warped switch ties are promptly replaced. Tamping, welding, and grinding practices are continuously improving.

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