FAST Facility for Accelerated Service Testing
TECHNICAL NOTE

FAST/TTC/TN-80/04 March 24, 1980

EVALUATION OF RAIL WEAR AT THE FACILITY FOR ACCELERATED SERVICE TESTING

SUMMARY

The rail metallurgy experiment at the Facility for Acceleration Service Testing (FAST) is intended to provide information on the wear and failure behavior of a variety of rail metallurgies under unit train operations. Results from two metallurgy experiments are presented; the demarcation between them occurred at 135 million gross tons* (MGT). In the first experiment, a condition of underlubrication existed up to 40-45 MGT, whereafter the state of lubrication could be described as generous. A state of generous lubrication existed throughout the entire second experiment. Rail head profile measurements taken in both the first and second experiments revealed that head hardened and chrome molybdenum rail exhibited the best resistance to high rail curve wear. In the first experiment, a strong lubrication:metallurgy interaction existed, causing the premium metallurgies to benefit less than standard rail from conditions of generous lubrication. In the underlubricated condition (first experiment) only, the 1:14 tie plate cant produced about 20% more gage face and head loss wear than did the 1:30 and 1:40 cants. Position-in-curve effects were dependent upon the level of lubrication. When generous lubrication permitted accumulation of greater tonnage on the rails, fatigue failure both in the head of the rail and in weldments became the dominant failure mode.

Standard rail exhibited the greatest number of rail head fatigue type failures. In the first experiment, fully heat-treated rail exhibited as many head failures as did standard rail, but in the second experiment, it exhibited only one head failure. Chrome molybdendum rail had no head failures in either experiment. High silicon and head hardened rail were intermediate in behavior. In the second experiment, head hardened rail exhibited the greatest number of weld failures, with standard rail next. The 1:40 tie plate cant was associated with far fewer fatigue and plant weld failures than were the 1:14 and 1:30 tie plate cants.

INTRODUCTION

The rail metallurgy experiment at FAST has as its primary intent the development of rail wear information under a controlled environment. However, useful information on rail and weld failure behavior has also been forthcoming.

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*Metric conversions follow text.

RPI
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The FAST Track is a specially constructed 4.8-mi loop divided into 22 sections where specified combinations of track components and structures are installed for testing. It contains 2.2 mi of tangent, 0.4 mi of 3° curve, 0.3 mi of 4° curve, and 1.1 mi of 5° curve; the remaining 0.8 mi is in transitional spirals.

The FAST consist is made up of 4-axle locomotives normally hauling a 75-car, 9,500-ton train. The majority are 100-ton hopper or gondola cars; the remainder are 100-ton capacity tank cars and laden trailer-on-flat cars. The average train speed is 41 mi/h with a maximum speed of 45 mi/h.

Each test run begins in the afternoon, continues all night, and ends the next morning, five days a week. Each run makes approximately 120 laps producing approximately 1 MGT on the track and about 600 mi on the cars.

The rail metallurgy tests have been undertaken in Sections 03 and 13. Section 03 is a 5° curve, 3,600 ft long. The north half is on a 0.9% grade, while the south half is virtually level. Section 13 is a 4° curve, 1,250 ft long, level throughout its length (figure 1).

As of June 1979, two rail metallurgy experiments had been completed. The first extended for 135 MGT and the second extended for an additional 290 MGT (until 425 MGT). At the beginning of the first experiment, rail lubrication was provided from track lubricators in Sections 05 and 17 only. However, between 30 and 50 MGT, two additional lubricators were installed in Sections 02 and 18 and the Section 17 lubricator was moved to Section 14. Thus, two regimes of behavior, one of underlubrication and the other of generous lubrication, existed in the first experiment with a transition at 40-45 MGT. In the second experiment, only the generous state of lubrication was used.

The physical layouts of the first and second experiments in Section 03 are shown in figure 2. In both experiments, the same five metallurgies and three tie plate cants were the primary test parameters. However, the change in physical layout was necessitated by an unexpectedly large number of weld failures in the first experiment and by a concern that the short lengths (62-78 ft) of each metallurgy segment in the first experiment would produce nonrepresentative wear results. Possible position-in-curve effects were compensated for by providing at least three replications of the metallurgies around the curves. In each experiment, Section 13 was configured almost identically to Section 03, except for a reduced number of metallurgies and the use of 1:40 tie plate cant throughout.

Section 03 was laid with the American Railway Engineering Association (AREA) standard carbon (Std), high silicon (HiSi), chrome molybdenum (CrMo), fully heat-treated (FHT), and head hardened (HH) rail, all in rail sections of 132 lb/yd and 136 lb/yd in the first experiment; 140 lb/yd rail replaced the 132 lb/yd rail (FHT) in the second experiment. In Section 13, in the first experiment, four metallurgies were tested--Std, HiSi, FHT, and HH, each replicated four times. All rail in Section 13 was 115 lb/yd.

The average ladle chemistries of the rails tested in the first experiment are given in table 1. With the exception of the FHT rail tested in Section 03, which had a carbon content slightly less than 0.70 weight percent (w/o), and the Std rail tested in Section 13, which had a carbon content just under

0.75 w/o, all metallurgies had average carbon contents in the range of 0.76-0.80 w/o. The average manganese levels ranged from 0.81 w/o to 0.88 w/o.

Wear measurements were taken with profilometers that produce transverse 1:1 tracings of the rail head, beginning at the fishing surface under one side of the head and tracing around to the other. Correction procedures were applied to compensate (sometimes only partially) for instrument and operator variability. In addition, a change in profile correction procedure was introduced at 80 MGT; this change was believed to be responsible for the transients in wear data observed at that tonnage. Measurements were taken at approximately 20-25 MGT intervals with a minimum of two measurement sites on each test rail.

Throughout the first experiment, the overall instrument standard deviation for head area of the calibration rail was 2.6%; the best instrument had a standard deviation of 0.21%. Instrument variability accounted for approximately 1% of the total variability of the entire data base.

Profiles were digitized and then processed to produce the dimensions shown in figure 3 along with gross area (complete area above lines projected from fishing surfaces) and total head area (above projections from fishing surfaces, but within the original profile). Portions of these data have been subject to two types of statistical analysis by independent organizations. The Association of American Railroads (AAR), Washington D.C., made the more elaborate (and more rigorously correct) analysis of covariance using all original data for decisions about statistical significance wherein wear is described by a linear wear model. For data taken before the lubrication transition only, the best-fit line was not constrained to go through the mean zero wear at 0 MGT, but it did, in fact, come very close to doing so.

The Transportation Systems Center (TSC), Cambridge, Massachusetts, made the second (simpler) analysis. It also used a linear wear model and determined the parameters of the model by regression techniques. Testing for statistical significance, however, was applied only to the wear rates derived from the regression analysis and did not utilize the original data.

Results of both analyses will be presented for gage face wear rates in the first experiment in Section 03. The more elaborate method has also been utilized to study the head height loss and area reduction indicators of wear in Section 03, first experiment. The simpler method has been applied alone to the gage face wear rates from Section 13 in the first experiment and from Section 03 in the second experiment; at this time, results are available only for the high rail.

DISCUSSION

Wear

The extremes of profile shape which occur after approximately 130 MGT of combined underlubrication and very generous lubrication are illustrated in figure 4. The Std rail has a well developed "front porch" formed by metal flowing down the face. This porch forms in the underlubricated regime. All other metallurgies are far less susceptible to this behavior than is Std rail.

The gage face loss wear data of all five metallurgies on the 1:40 cant tie plate in Section 03 are shown in figure 5. Here, the wear values represent the differences of individual gage face dimensions (ΔD7) from the intercept of the best-fit straight line at 0 MGT. The scatter of Std and HiSi rails was substantially greater than that of the other metallurgies because there were about 10 different heats of Std and HiSi rail, but only one or two different heats of the other metallurgies.

The wear rates for the three different measures of wear above and below the transition in lubrication and for the different tie plate cants are summarized in table 2. The results indicate that both tie plate cant and metallurgy have significant effect on all three measures of wear. Wear rates above 45 MGT are substantially lower (by 80 to 90%) than those below 45 MGT. In the underlubricated regime (<40 to 45 MGT), the 1:14 tie plate cant yields about 20% higher wear rates for gage face wear and head area loss, while the 1:40 cant produces higher rates of head height loss (on average 27%). Typically, HH and CrMo wear rates are lower than those of the other metallurgies. HH has the lowest gage face wear, but CrMo has the least head height loss. The degree of difference between the behavior of the different metallurgies is less above 45 MGT than below 45 MGT, which does suggest the presence of a metallurgy:lubrication interaction.

To explore this last point further, Figures of Merit (FM) were calculated for all the metallurgies in each lubrication regime to provide a quantitative average ranking of each metallurgy. The FM is the number of times better a premium rail wears (on the average) than does Std rail tested under the same condition. The FM are given in table 3.* This type of presentation reveals clearly that generous lubrication tends to decrease the advantage in wear resistance achieved by using a premium metallurgy.

The decrease is most marked for gage face wear where only HH rail seems significantly better than Std rail in the generously lubricated regime. Also, the ranking of metallurgies is not the same for the head area and gage face loss measures of wear. Although FHT rail is no better than HiSi rail in its resistance to gage face loss, it is significantly better in terms of head area loss.

Tables 4 and 5 illustrate that the agreement between the two different types of analysis is very good even if the transition tonnage is shifted slightly to 40 MGT. When the lubrication transition was set at 40 MGT, the standard deviations of the gage face wear rates were between 0.00021 in/MGT and 0.00033 in/MGT for all metallurgies other than Std rail which was 0.00056 in/MGT. If the transition were shifted to 45 MGT, the wear rates change very little, but the standard deviations in the majority of cases would be reduced somewhat. This suggests that 45 MGT is a slightly better transition than 40 MGT. Based on observed standard deviations, the FM for gage face wear have a tolerance (of extremes) of +25% to -15%, in the underlubricated regime.

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*However, the reader is cautioned to remember that the Figures of Merit represent average wear rates of each metallurgy and are derived from a widely scattered data base with unbalanced numbers of heats among the different metallurgies. Thus, the Figures of Merit must be considered the best average ranking of the different metallurgies obtainable within the limitations imposed by testing.

The simpler (TSC) method of analysis is more easily implemented and was, therefore, used to test for position-in-curve effects and to provide a preliminary glimpse at the data from Section 13 (first experiment) and from Section 03 (second experiment).

The magnitude of the position-in-curve effect in Section 03 is given in table 6. In the underlubricated regime, the Section 04 end of Section 03 produced slightly higher wear rates on average than did either the middle or the Section 02 end. However, in the more generously lubricated regime, the relative differences were greater with the highest wear occurring at the center of the curve. Again, the behavior was not strongly dependent on where the lubrication transition was selected. Table 7 summarizes results of statistical testing for significance and shows that indeed the position-in-curve effect tended to increase at the expense of the primary metallurgy and cant effects as lubrication improved. However, these statistical tests consider all members of each group of variables (metallurgy, tie plate cant) together rather than by pairs. Therefore, when significance is indicated for a particular variable, it may not be possible to identify whether or not an individual is significantly different from its associates, except in extreme cases.

Gage face wear rates from Section 13 (first experiment) are summarized in table 8. The same general pattern was observed as that occurring in Section 03 except that a statistically significant position-in-curve effect was not noticed. HH rail gave the highest resistance to gage face wear and FHT rail was better than HiSi and Std rail. In the more generously lubricated regime above 40 MGT, all metallurgies behaved essentially the same.

Before reporting the results from the second experiment in Section 03, it will be fruitful to comment briefly upon the effect of heat-to-heat variations occurring in the Std rail of the first experiment. Figure 6(A) illustrates the behavior of four high-wear-rate heat/tie plate cant combinations. If these four combinations were removed, the Std rail data set would be much more compact--as shown in figure 6(B). However, for all three measures of wear, removal of these combinations would reduce average wear rates by only 10%, and the FM would be reduced also by a corresponding 10%.

Preliminary gage face wear results from the second experiment in Section 03 are summarized in table 9 alongside a comparison with results from the first experiment. The results in terms of FM are in close agreement with those from the generously lubricated regime of the first experiment, except that the CrMo rail performed somewhat better than did the HH rail. The reader must exercise some caution in deciding whether the difference in FM or CrMo and HH is real, because it was only in the Section 02 end that both appeared to be appreciably different. Overall, the observed wear rates in the second experiment were only 1/3-1/2 the magnitude of those observed in the first experiment.

Table 10 summarizes the pertinent statistical information. Tie plate cant did not appear to be significant, although the position-in-curve effect did appear to be statistically significant with tie plate cant included in the analysis. If tie plate cant were removed as a variable, the statistical strength of the position-in-curve effect would be weakened.

It will be informative to consider how these results compare with those from other investigations. Figure 7 shows the range of wear rates (head area loss) for the metallurgies tested in Section 03, 5° curve relative to those reported by Curcio, et al.,[1] Rougas,[2] and Hay, et al.[3] The data of Hay, et al., are shown as average curves. FAST data are consistent with the trend of results reported by Curcio, et al., for unit train type operations in Australia. FAST wear in the underlubricated region was substantially more severe than that reported by Hay, et al., for more general types of railroad service in the United States and even that reported by Rougas for heavy unit train service on the Bessemer and Lake Erie Railroad was less severe than FAST wear.

The expression proposed by Kalousek and Bethune[4] for volumetric wear can be recast into the form:

$$\frac{V_1}{V_2} = \frac{C_1}{C_2} \cdot \frac{H_2^{\alpha_2}}{H_1^{\alpha_1}}$$

where:

V = volumetric wear,

H = hardness,*

1 and 2 = different metallurgies, and

C and α = empirical constants.

The presumption is that lateral force, lateral and vertical creep, and the angle of the gage face to the lateral force vector are not functions of metallurgy. Thus, the ratio V_1/V_2 is really a FM if V_1 is taken to represent Std rail. If volumetric wear is thought to be best represented by head area loss, the FAST FM can be plotted as shown in figure 8 against the gage face hardness ratio.

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* Hardnesses were measured with a portable full-load (3,000 kg) Brinell tester applied directly to the gage face after completion of testing in the second lubrication regime of the first experiment.

[1] Curcio, P., Marich, S., and Nisich, G., "Performance of High Strength Rails in Track," Sessions 313, Paper 1.10, Heavy Haulage Conference, Perth, Australia, September 1978.

[2] Rougas, M., "Observations on the Effect of Heavy Wheel Loads on Rail Life," 1975 Technical Proceedings of the 12th Annual Railroad Engineering Conference.

[3] Hay, W.W., Reinschmidt, A. J., Bakas, P. T., and Schuch, P. M., UILU Report Eng 76-2002 NTIS PB 252024.

[4] Kalousek, J., and Bethune, A. E., "Rail Wear under Heavy Traffic Conditions," C.P. Ltd., Department of Research Report.

Two different linear plots (α_1, $\alpha_2 = 1$) appear to obtain for the premium rails--one for heat-treated rails and the other for alloy rails. Furthermore, the slopes of the lines appear to be a function of lubrication, with the heat-treated rails being less influenced by lubrication than were alloy rails. Whether the gage face wear results of the CrMo rail in the second experiment are a contradiction to this will not be known until the head area loss data are analyzed and hardnesses are taken on the gage face.

Rail/Weld Failure

The very low wear rates of Std rail observed under conditions of generous lubrication would project to a total rail life (on a 5° curve) of between 750 MGT (first experiment results) and 1,250 MGT (second experiment results) for a 3/4" gage face wear condemning limit. However, appreciable amounts of rail would have to be replaced for reasons of fatigue long before these tonnages would be reached. Indeed, FAST has been a prodigious generator of fatigue failures, of both rail and weldments, in the well-lubricated regime.

Table 11 summarizes the total number of weld and head type failures which have occurred to 250 MGT in the first and second metallurgy experiments.

In the first experiment, 24% of the plant welds failed in Section 03 and 27% in Section 13. Although only 22 (Section 03) and 10 (Section 13) field welds (thermite) were placed in the original construction, the total number of field weld failures exceeded these numbers because replacement welds also failed. These weld failures, along with rapid wear in the underlubricated regime, necessitated the rerailing of Sections 03 and 13 at 135 MGT. However, limited tonnage was accumulated in the first experiment and relatively few head-type defects occurred; of those, three each were in FHT and Std rail, two were in HH, while the remaining one was in HiSi.

In the second experiment, less wear and greater tonnage permitted the generation of more head-type defects. In addition, redesign of the experiment configuration reduced the number of plant weld failures to 8% in both Sections 03 and 13. Field weld failures, although reduced in number, remained at an inconveniently high level.

Not all of the rail defects should be considered true fatigue defects. Four of the head defects which occurred in Section 03 were at or very near the ends of metallurgy segments, so they may be related to mechanical joint assemblies and/or maintenance problems. Were these four defects removed from consideration, along with five head defects associated with an apparently very dirty heat of Std rail in Section 13[5], the overall defect rates would drop to 20/mile of track for Section 03 and 10/mile for Section 13.

Figure 9 shows the location by metallurgy and tie plate cant for plant weld and head type defects in the high rail of Section 03. Without counting those near segment ends, Std rail had five head-type fatigue defects for a rate of 44/mile (of high rail) and HiSi followed with only two defects for a

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[5] Fleming, L. D., and Wisnowski, M. J., "Investigation of a Failed Rail from FAST," AAR Report #R-371, May 1979.

rate of 18/mile. HH rail had only one head defect that was not at a segment end or weldment, yielding a defect rate of 9/mile. FHT had only one head defect and it was at a segment end. CrMo had no head type failures.

HH rail had the most plant weld failures--six. Std rail had two, while CrMo and FHT rail had only one plant weld failure each within the metallurgy test section. In Section 13, Std rail had two plant weld failures, while FHT and HiSi rail had one failure each.

By tie plate cant, the 1:14 cant was associated with nine failures (four plant weld and five head defect), the 1:30 cant with ten failures (five plant weld and five head defect), and the 1:40 cant with three failures (one plant weld and two head defect). However, some of these did occur near segment ends (figure 9) and therefore, may be considered suspect. In addition, the experiment design placed the 1:14 and 1:30 cants in the midregion of the curve, while the 1:40 cant was positioned at the ends of the curve under Std, HH, and HiSi rails.

The relationship between the rail failure and tonnage is shown in figure 10 for two of the rail metallurgies tested in Section 03. Also shown for comparison is the behavior of Std rail in FAST Section 22 (CWR, tangent track) and that of rail in some western U.S. mainline service.[6] In Section 03 (5° curvature), the failure percentile of Std rail at 200 MGT was approximately ten times that of Std rail in Section 22 (tangent track) and more than 100 times the average of rail in some western U.S. mainline service. HiSi rail has a slightly lower failure rate than does Std rail. There were insuffficent fatigue failures of FHT, HH, and CrMo rail to draw any quantitative assessment of how much better they might be than Std rail. Although the rail population of each metallurgy is small and a larger sampling might have produced less extreme behavior, the very large differences between FAST failure behavior and that of more conventional U.S. railroads service suggest that the heavier wheel loads and unit train character of the FAST consist have contributed to a substantial increase in rail fatigue failure rate.

A typical detail fracture from a shell is illustrated in figure 11. Each alternating growth ring represents one day of operation in a given direction. The growth pattern is consistent with the calculations of Steele[7] for a centrally located defect growing under the FAST vertical load spectra and lateral loads near 10 kips. This loading would serve to increase the cyclic longitudinal stress by about 50%, as determined by McConnell and Perlman.[8]

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[6] Stone, D. H. "Track Train Dynamics Contributions to Rail Metallurgy," AREA Bulletin, Vol 80, June-July 1979.

[7] Steele, R. K., "Fatigue Crack Growth and Fracture Mechanics Consideration for Flaw Inspection of Railroad Rail," Defection of Material and Fabrication Defects in the Transportation Industry, ASNT Conference, June 11-13, 1979, Norfolk, Virginia.

[8] McConnell, D. P., and Perlman, A. B., "An Investigation of the Structural Limitations of Railroad Track," June 1979, Interim Report (Tufts University), DOT-TSC-1575.

Figure 12 illustrates the fracture appearance of frequently occurring plant weld and field weld failures. Typically, both have a nearly horizontal web crack extending to either side of the weld region. However, the plant weld failure originates from a transverse vertical crack which develops at the edge of the shear drag region under the gage side head-web fillet. A substantial period of vertical fatigue growth (> 20 MGT) frequently occurs before the crack turns horizontal in the web. On the other hand, the field weld failure sometimes appears to be initiated in the heat-affected zone, with the crack then propagating through the weld itself.

Conclusions

The wear tests in the first and second metallurgy tests have shown that HH and CrMo rail exhibited the best resistance to wear under the FAST loading environment. There existed a strong lubrication:metallurgy interaction and under conditions of generous lubrication, the premium metallurgies did not appear to benefit as much from lubrication as did Std rail.

In the underlubricated wear regime, the 1:14 tie plate cant produced about 20% more gage face and head area loss wear than did the other cants. However, the 1:40 cant produced somewhat greater head height loss. The tie plate cant effect was diminished considerably under conditions of generous lubrication, and position-in-curve effects depended upon the level of lubrication--they reversed in character as lubrication level varied from one extreme to another.

When conditions of generous lubrication served to extend rail life substantially, fatigue failure--both in the head of the rail and in weldments--became the dominant failure mode. At 250 MGT of traffic, the true FAST head defect rate was near 10-20/mile. The fatigue failure rates of Std rail in a 5° curve track and in tangent track were approximately 100 and 10 times, respectively, that reported for rail in some western U.S. mainline service.

Data analysis/preparation for this Technical Note was provided by Dr. M.B. Hargrove, Manager, Office of Engineering Economics, Association of American Railroads, Washington D.C.; Dr. R.K. Steele, Manager of Metallurgy, Federal Railroad Administration, Transportation Test Center, Pueblo, Colorado; Mr. F.S. Mitchell, Track Engineer/Analyst, Association of American Railroads, Transportation Test Center, Pueblo, Colorado; and Mr. R.E. Young, Research Analyst, H. H. Areospace Co., Cambridge, Massachusetts.

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Metric Conversions

1 in = 25.4 mm
1 ft = 0.3048 m
1 mi = 1.6094 km
1 ton = 0.907 Mg
1 MGT = 0.907 MGMg

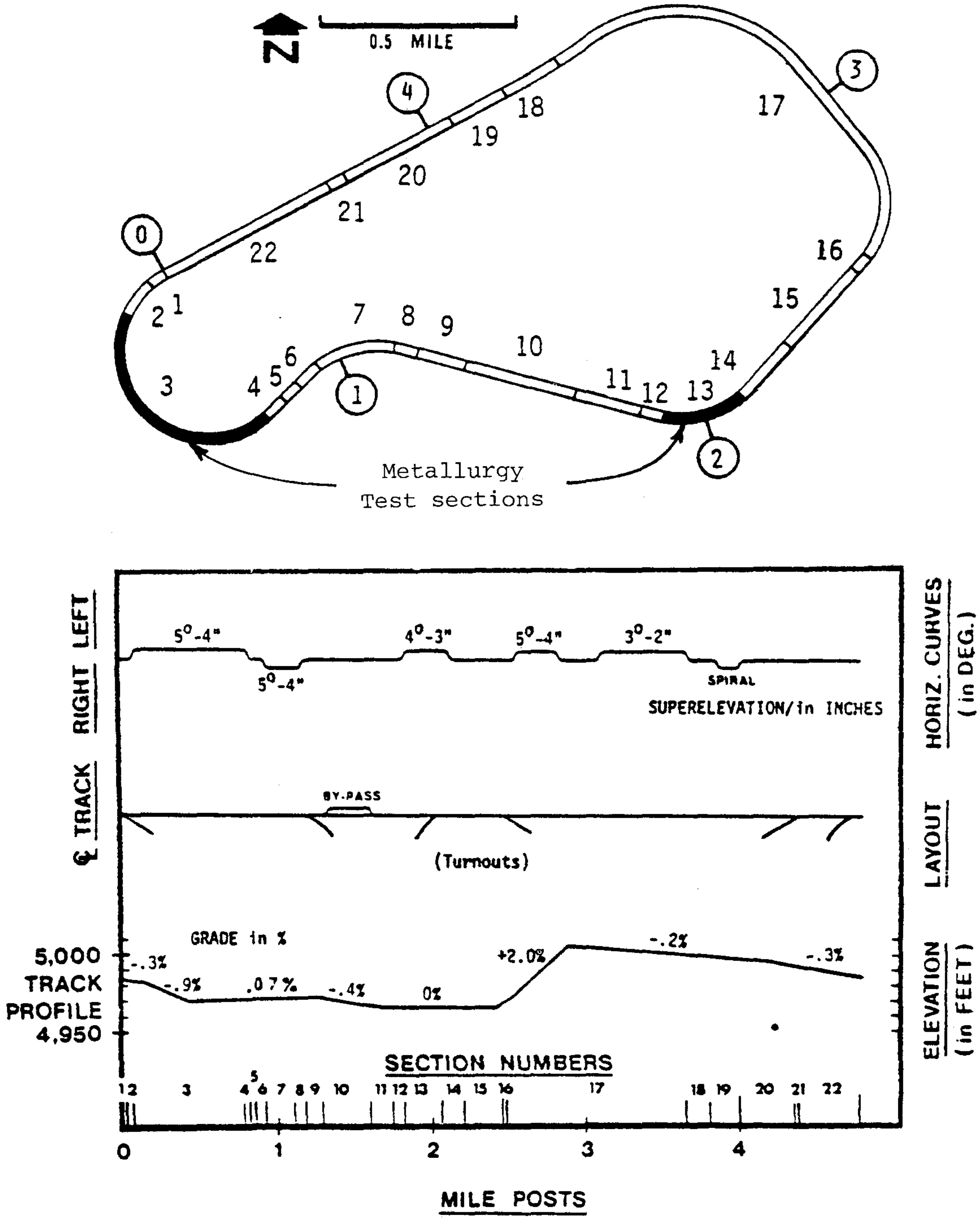
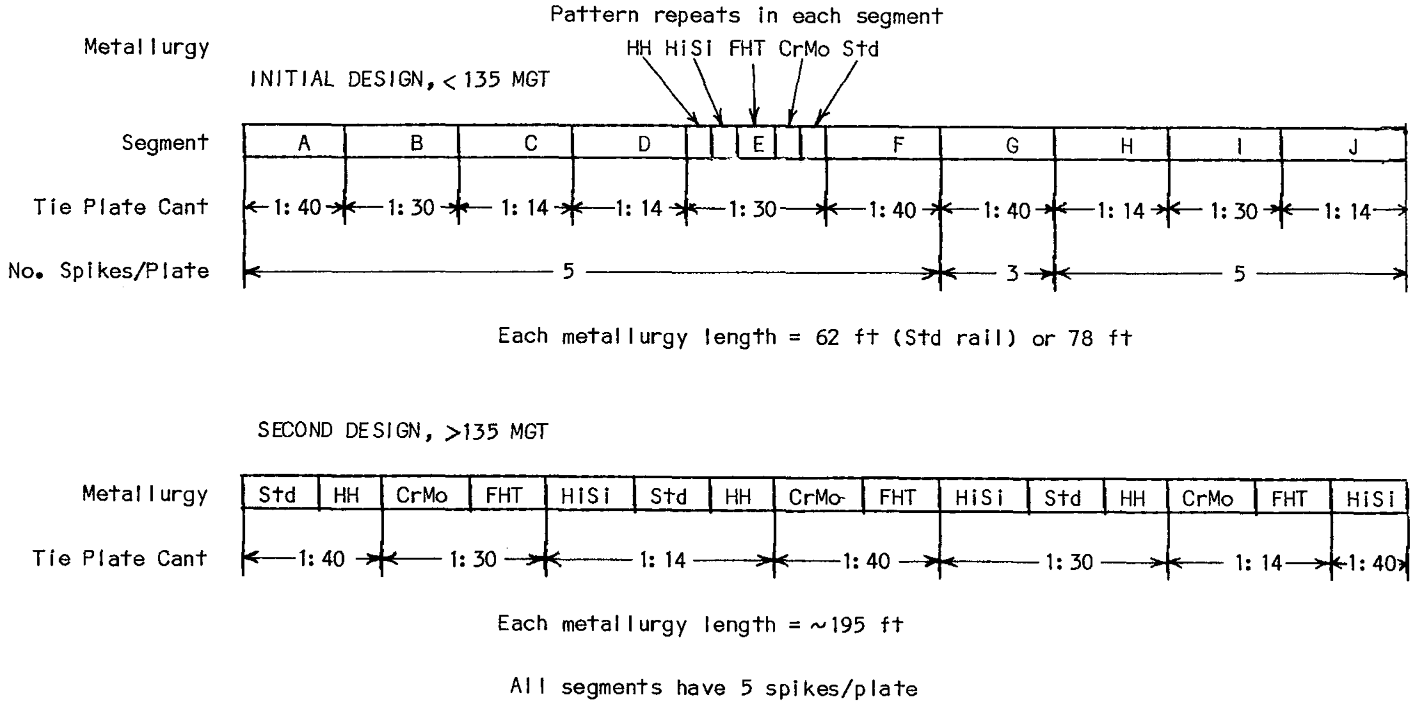


FIGURE 1. DIAGRAM OF THE FAST TRACK.



Each metallurgy length = 62 ft (Std rail) or 78 ft

Each metallurgy length = ~195 ft

All segments have 5 spikes/plate

FIGURE 2. LAYOUT OF FAST SECTION 03.

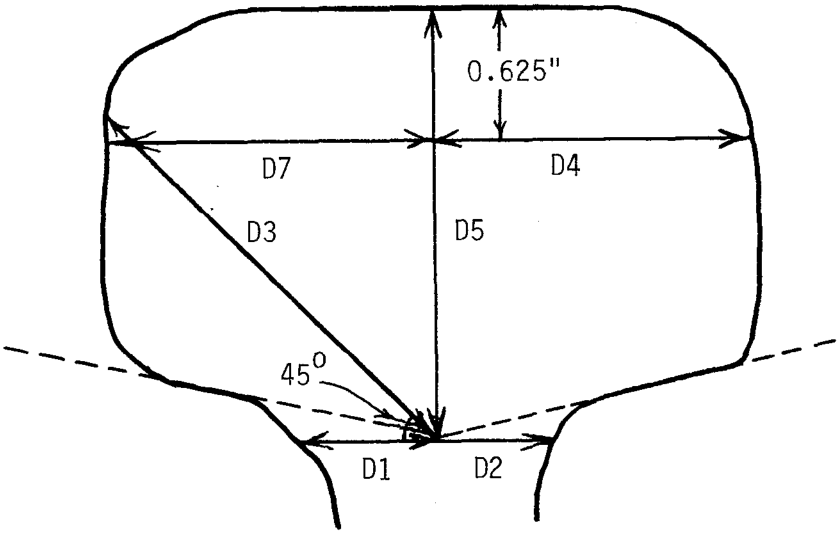


FIGURE 3. PROFILE DIMENSIONS.

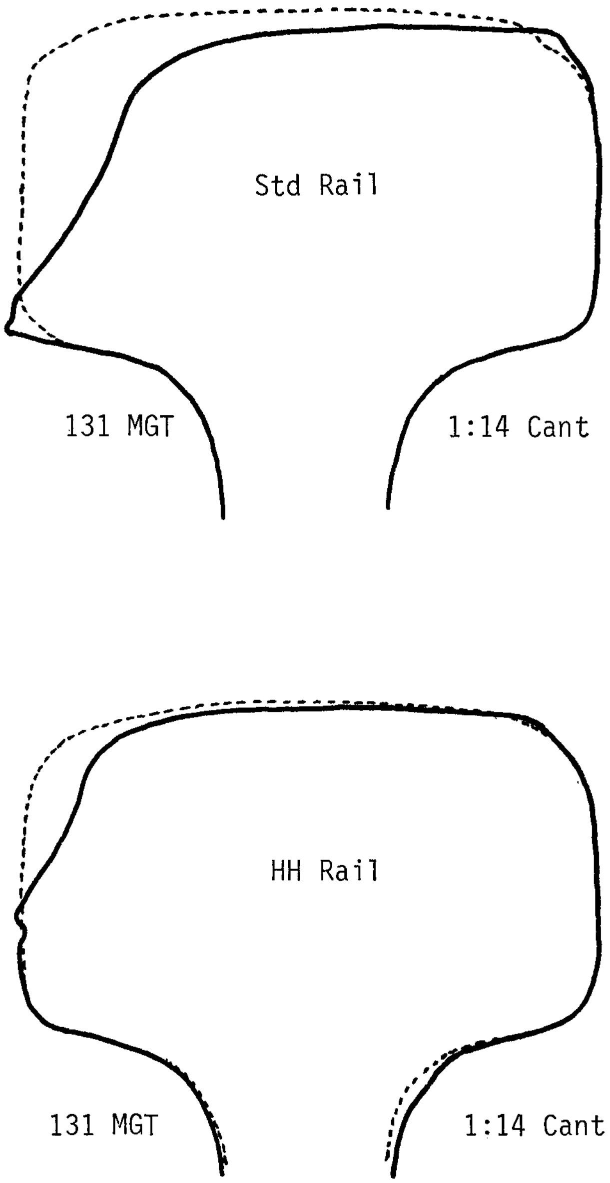
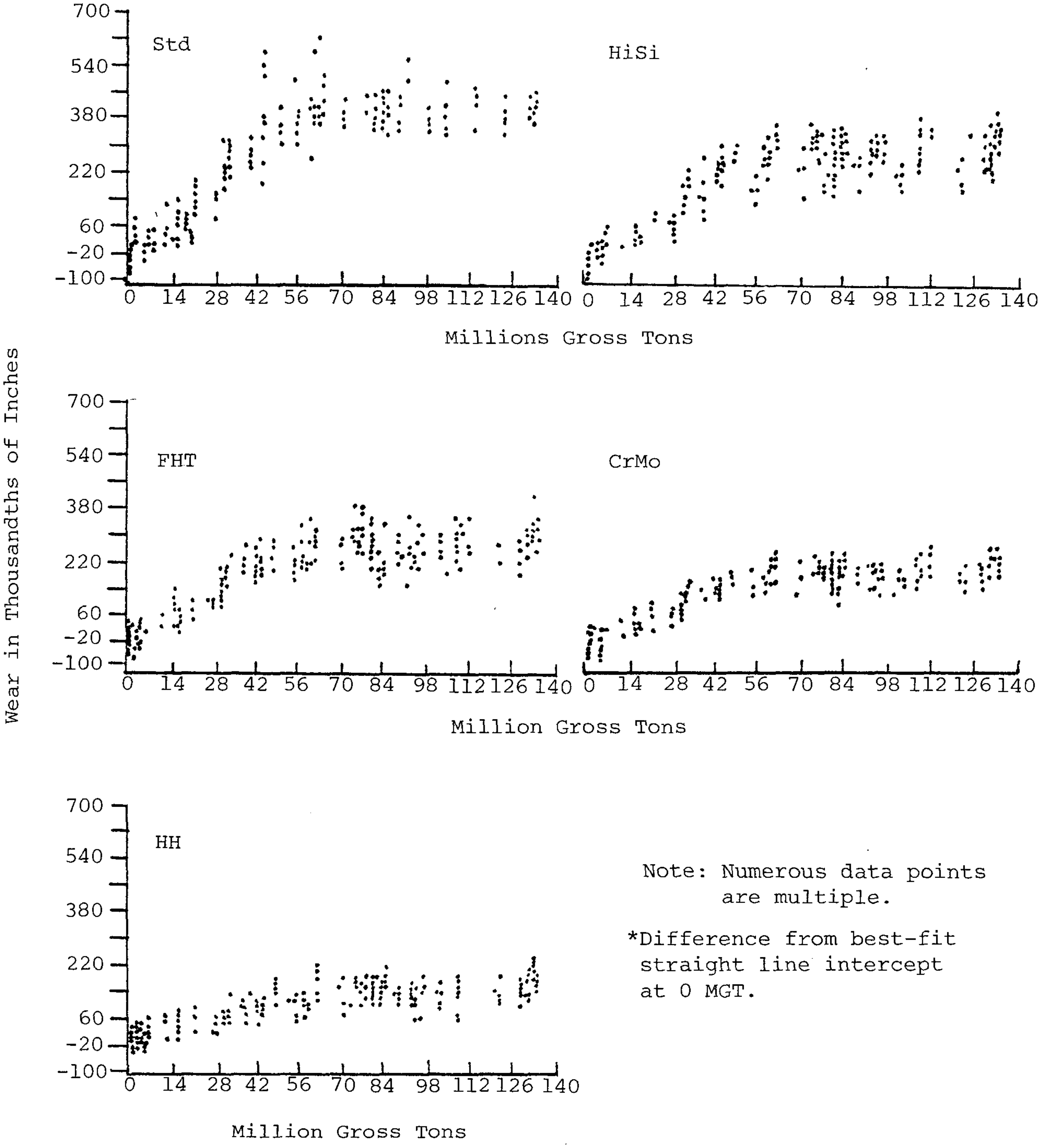


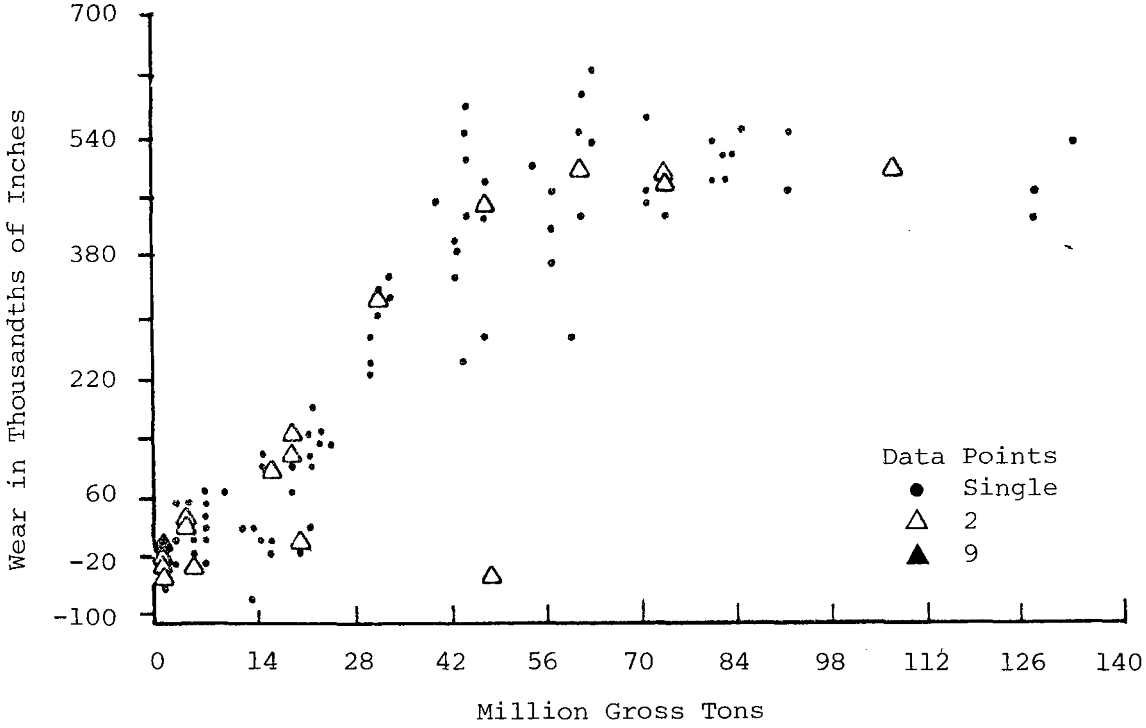
FIGURE 4. EXTREMES OF PROFILE APPEARANCE.



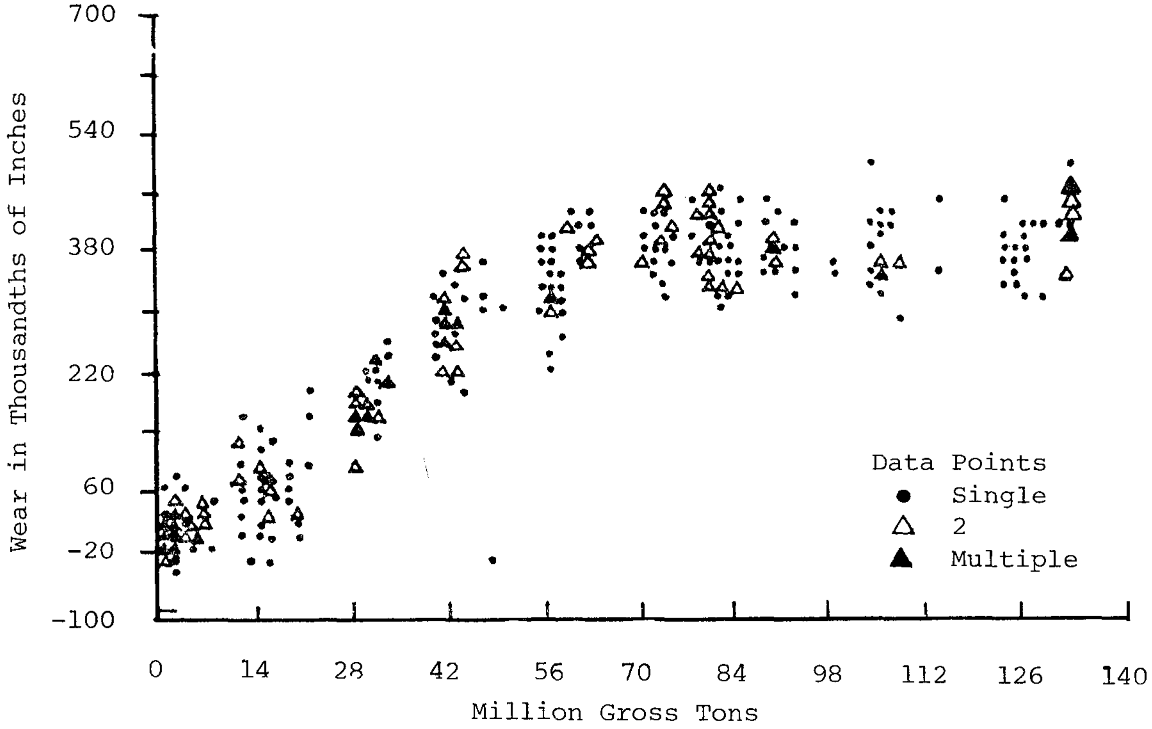
Note: Numerous data points are multiple.

*Difference from best-fit straight line intercept at 0 MGT.

FIGURE 5. GAGE FACE LOSS WEAR* OF ALL FIVE METALLURGIES ON 1:40 CANT TIE PLATES IN SECTION 03.



A. High-Wear-Rate Combinations Alone.



B. Remaining Combinations When High-Wear-Rate Combinations Are Removed.

FIGURE 6. HIGH-WEAR-RATE HEAT/TIE PLATE CANT COMBINATIONS.

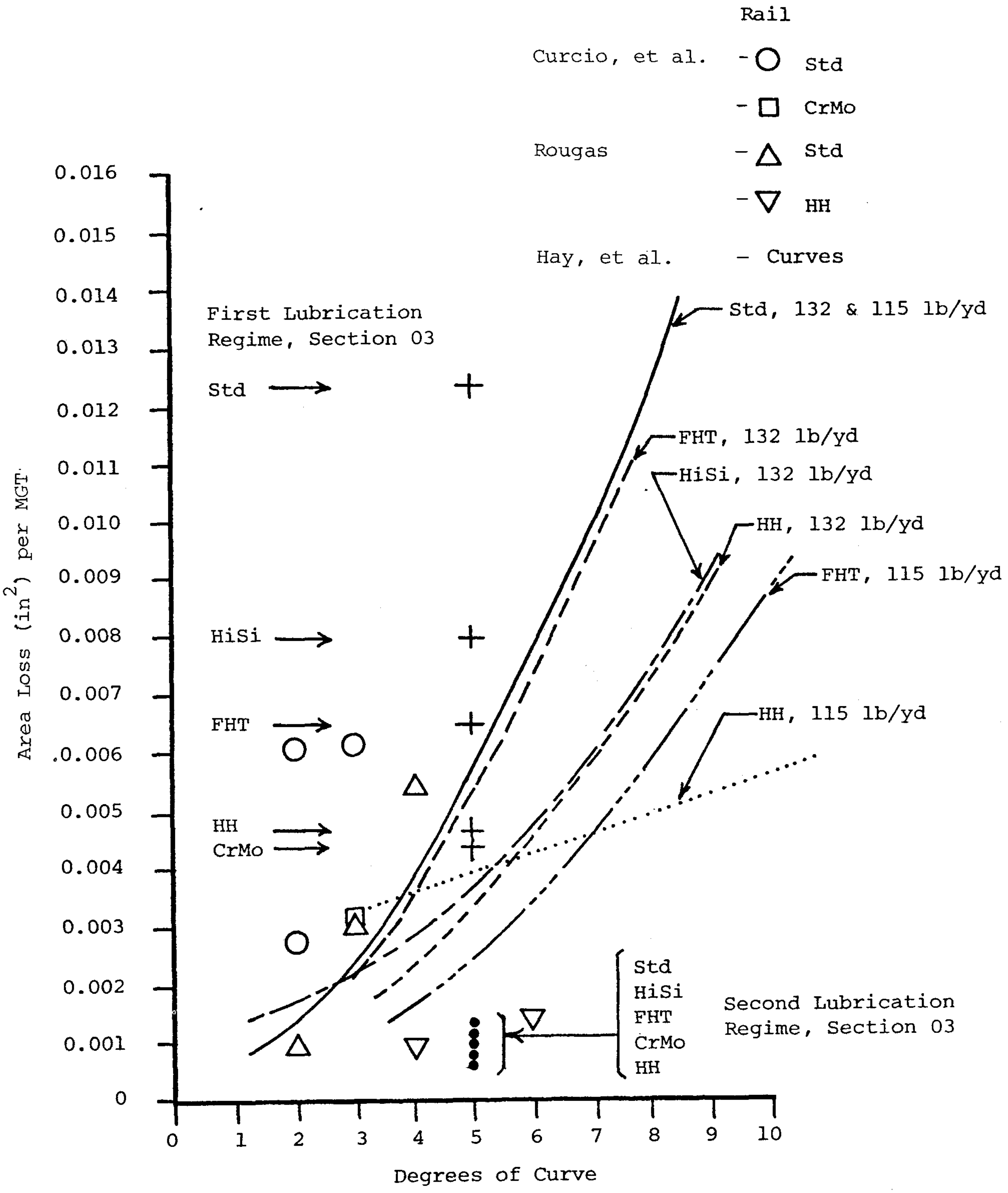


FIGURE 7. COMPARSION OF WEAR RATE DATA FROM DIFFERENT SOURCES WITH THAT FROM THE FIRST FAST EXPERIMENT.

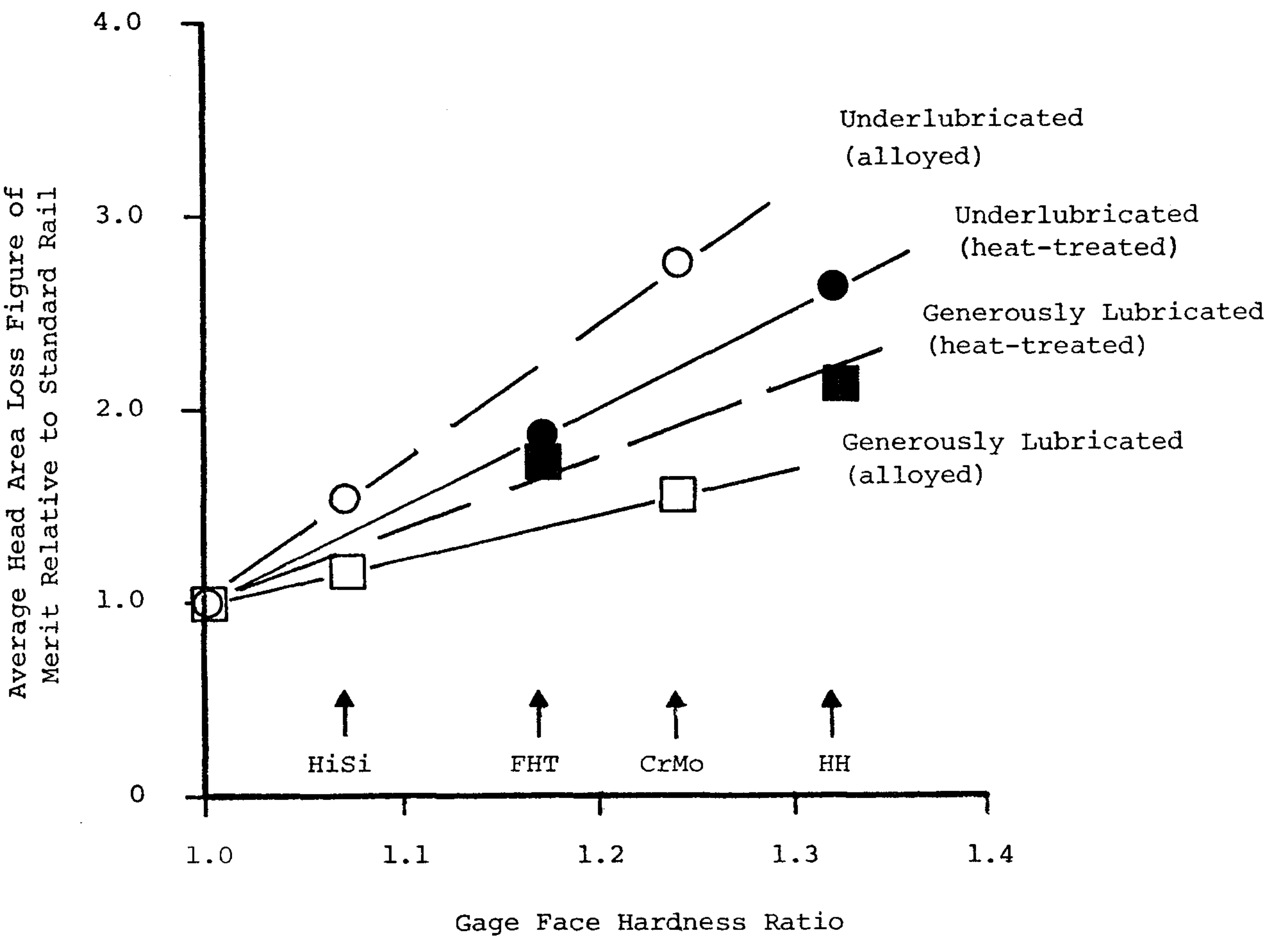


FIGURE 8. EFFECT OF RELATIVE GAGE FACE HARDNESS UPON HEAD AREA LOSS FIGURE OF MERIT.

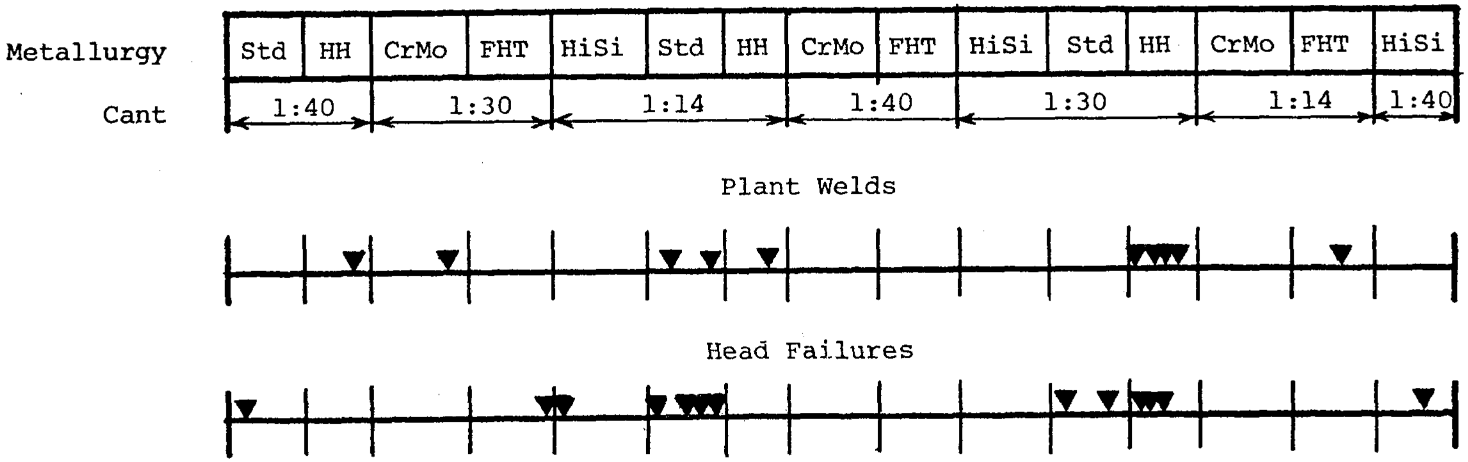


FIGURE 9. SECTION 03, RAIL/WELD FAILURE OCCURENCE
(HIGH RAIL ONLY).

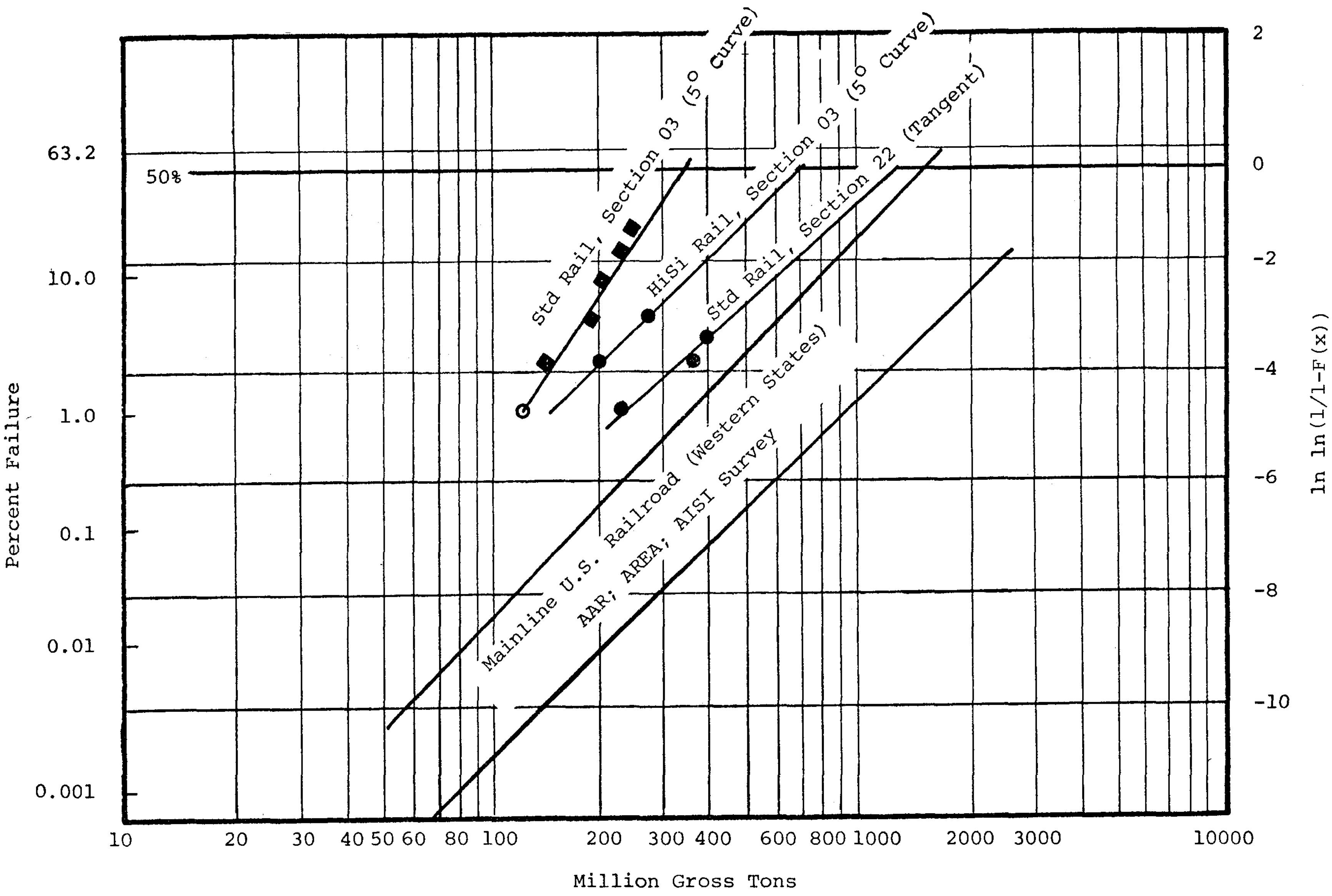


FIGURE 10. WEIBULL PRESENTATION OF FAST RAIL FAILURE DATA.

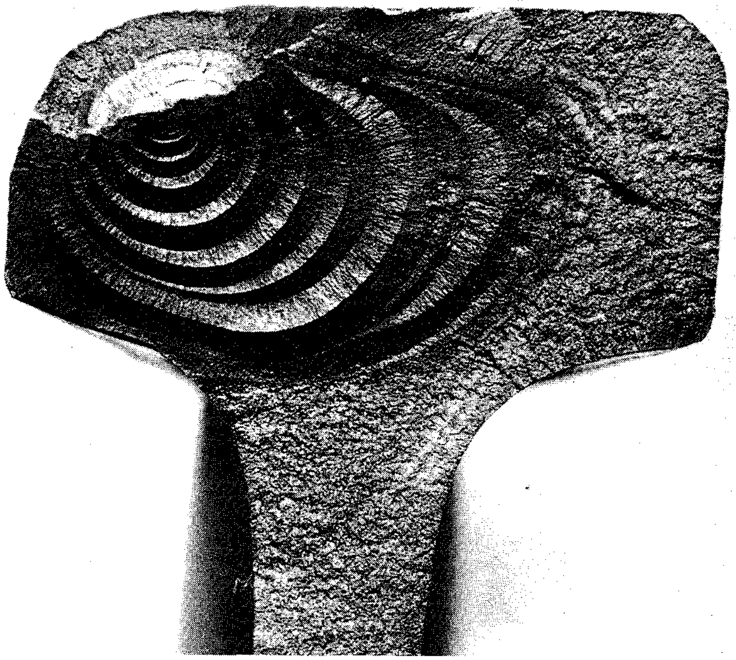
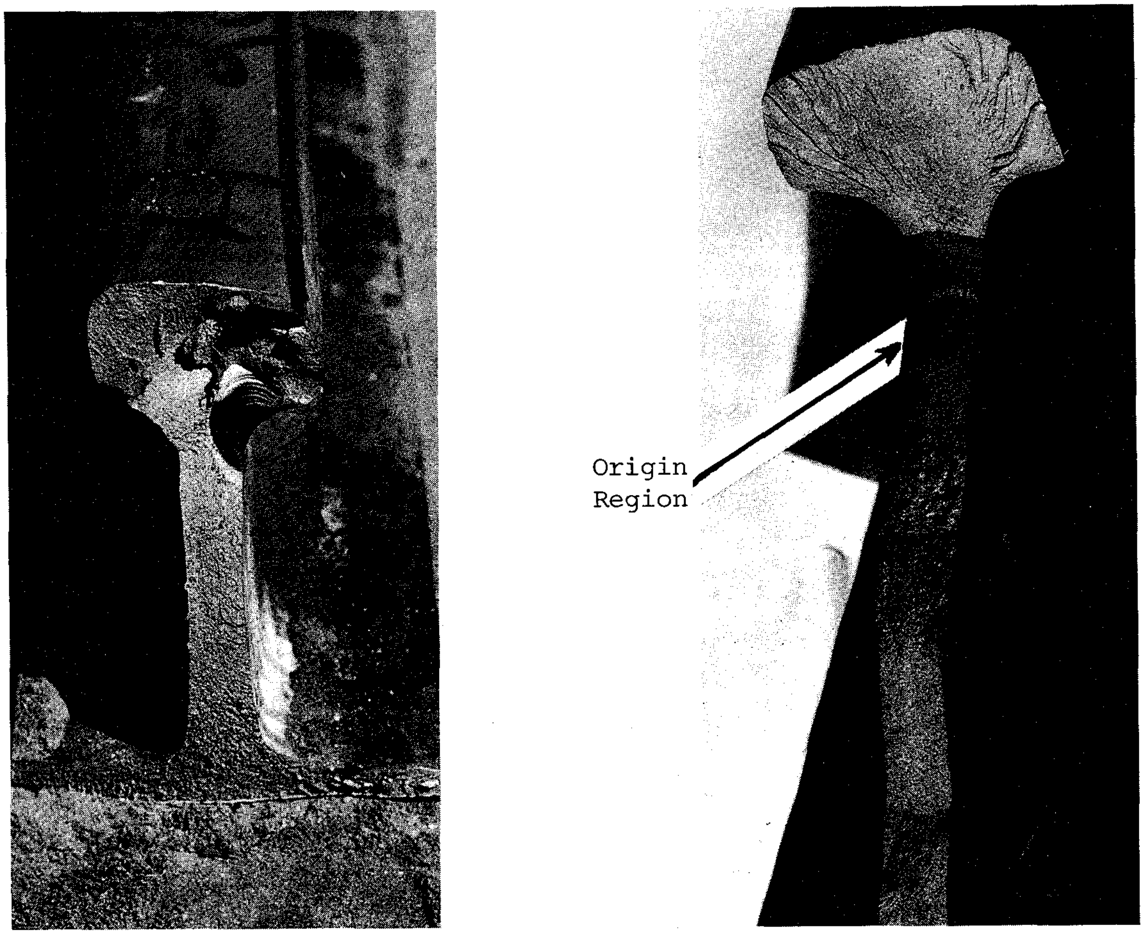


FIGURE 11. A DETAIL FRACTURE FROM SHELL, 1.25X.



A.

B.

FIGURE 12. WELDMENT FAILURES - (A) PLANT WELD FAILURE ORIGINATING AT SHEAR DRAG REGION. (B) FIELD WELD FAILURE INITIATION IN THE HEAT-AFFECTED ZONE.

TABLE 1. AVERAGE CHEMICAL ANALYSES OF RAIL IN THE FIRST FAST METALLURGY EXPERIMENT.

Section	Rail Type	Weight Percent, w/o C	Mn	P	S	Si	Cr	Mo
Section 03								
	Std	0.78	0.86	0.027	0.025	0.15	--	--
	HiSi	0.76	0.86	0.028	0.027	0.63	--	--
	FHT	0.69	0.81	0.018	0.032	0.18	--	--
	CrMo	0.80	0.82	0.026	0.025	0.25	0.78	0.20
	HH	0.79	0.84	0.009	0.018	0.16	--	--
Section 13								
	Std	0.73	0.86	0.024	0.020	0.17	--	--
	HiSi	0.77	0.88	0.029	0.024	0.68	--	--
	FHT	0.77	0.81	0.020	0.041	0.15	--	--
	HH	0.77	0.88	0.015	0.025	0.18	--	--

TABLE 2. WEAR RATES ABOVE AND BELOW THE LUBRICATION TRANSITION FOR THE DIFFERENT TIE PLATE CANTS.

Tie Plate Cant

Metallurgy	1: 40		1: 14		1: 30	
Gage Face Loss, in/MGT	<45 MGT	> 45 MGT	< 45 MGT	>45 MGT	< 45 MGT	> 45 MGT
HH	0.00271	0.00030	0.00384	0.00090	0.00298	0.00054
HiSi	0.00579	0.00031	0.00707	0.00149	0.00513	0.00097
FHT	0.00550	0.00082	0.00658	0.00111	0.00548	0.00102
CrMo	0.00355	0.00059	0.00444	0.00111	0.00401	0.00097
Std	0.00809	0.00072	0.00835	0.00135	0.00778	0.00099
Head Area Loss, in ^{2}/MGT						
HH	0.00496	0.00046	0.00514	0.00092	0.00424	0.00097
HiSi	0.00812	0.00110	0.00907	0.00119	0.00708	0.00154
FHT	0.00704	0.00046	0.00667	0.00149	0.00627	0.00183
CrMo	0.00449	0.00092	0.00423	0.00107	0.00482	0.00085
Std	0.01287	0.00167	0.01245	0.00127	0.01229	0.00156
Head Height Loss, in/MGT						
HH	0.00127	*	0.00109	*	0.00090	*
HiSi	0.00144	*	0.00134	*	0.00122	*
FHT	0.00097	*	0.00056	0.00005	0.00079	*
CrMo	0.00073	*	0.00053	*	0.00052	0.00006
Std	0.00256	0.00001	0.00233	0.00011	0.00223	0.00030

* Indicates no significant wear.

TABLE 3. FIGURES OF MERIT ABOVE AND BELOW THE LUBRICATION TRANSITION FOR THE DIFFERENT TIE PLATE CANTS.

Metallurgy	Tie Plate Cant							
	1:40		1:14		1:30		Avg	
Gage Face Loss	<45 MGT	>45 MGT	<45 MGT	>45 MGT	<45 MGT	>45 MGT	<45 MGT	>45 MGT
HH	3.0	2.4	2.2	1.5	1.8	1.8	2.6	1.9
HiSi	1.4	1.3	1.2	0.9	1.0	1.0	1.4	1.1
FHT	1.5	0.9	1.3	1.2	1.0	1.0	1.4	1.0
CrMo	2.3	1.2	1.9	1.2	1.0	1.0	2.0	1.2
Std	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Head Area Loss								
HH	2.6	3.6	2.4	1.4	2.9	1.6	2.6	2.2
HiSi	1.6	1.5	1.4	1.1	1.7	1.0	1.6	1.2
FHT	1.8	3.6	1.9	0.8	2.0	0.8	1.9	1.8
CrMo	2.9	1.8	2.9	1.2	2.5	1.8	2.9	1.6
Std	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Head Height Loss								
HH	2.0	*	2.1	*	2.5	*	2.2	*
HiSi	1.8	*	1.7	*	1.8	*	1.8	*
FHT	2.6	*	4.2	*	2.8	*	3.2	*
CrMo	3.5	*	4.9	*	4.3	*	4.2	*
Std	1.0	*	1.0	*	1.0	*	1.0	*

NOTE: FM = Standard Carbon wear rate/premium metallurgy wear rate on specific tie plate cant.

* Indicates no significant wear.

TABLE 4. AVERAGE GAGE FACE LOSS (SECTION 03) COMPARISON OF RESULTS OF ANALYSIS FROM DIFFERENT SOURCES.

in/MGT / FM	Below Lubrication Transition			Above Lubrication Transition		
	AAR	T S C		AAR	T S C	
	< 45 MGT	< 45 MGT	< 40 MGT	> 45 MGT	> 45 MGT	> 40 MGT
Std	0.0081 1.0	0.0087 1.0	0.0091 1.0	0.0010 1.0	0.0011 1.0	0.0016 1.0
HiSi	0.0060 1.4	0.0060 1.4	0.0064 1.4	0.0009 1.1	0.0012 0.9	0.0015 1.1
FHT	0.0058 1.4	0.0057 1.5	0.0061 1.5	0.0010 1.0	0.0009 1.2	0.0013 1.3
CrMo	0.0040 2.0	0.0041 2.1	0.0042 2.2	0.0009 1.1	0.0011 1.0	0.0013 1.3
HH	0.0032 2.6	0.0031 2.8	0.0032 2.8	0.0006 1.9	0.0008 1.4	0.0009 1.8

TABLE 5. TIE PLATE CANT EFFECT (SECTION 03) (AVERAGE OF ALL METALLURGIES AND POSITIONS-IN-CURVE).

In/MGT

	<40 or 45 MGT			>40 or 45 MGT		
Cant	AAR (45)	TSC (45)	TSC (40)	AAR (45)	TSC (45)	TSC (40)
1:40	0.0051	0.0052	0.0056	0.00055	0.0008	0.0011
1:30	0.0051	0.0052	0.0056	0.00090	0.0011	0.0013
1:14	0.0061	0.0062	0.0064	0.00119	0.0012	0.0016

TABLE 6. POSITION-IN-CURVE EFFECT (SECTION 03) (AVERAGE OF ALL METALLURGIES AND TIE PLATE CANTS).

In/MGT

	< 40 or 45 MGT		> 40 or 45 MGT	
Location	45	40	45	40
Section 02 End	0.0052	0.0053	0.0010	0.0014
Middle	0.0053	0.0056	0.0016	0.0018
Section 04 End	0.0061	0.0067	0.0005	0.0008

TABLE 7. RESULTS OF STATISTICAL TESTS FOR SIGNIFICANCE OF THE SECTION 03 GAGE FACE WEAR RATES FOR DIFFERENT TIE PLATE CANTS AND POSITION-IN-Curve.

Effect Or Interaction	Observed "F"	Significance			
		99%		95%	
		"F" Req'd	Yes/No?	"F" Req'd	Yes/No?
<u>< 40 MGT:</u>					
Cant	7.98	6.23	Yes	3.63	Yes
Pos-in-Curve	16.79	6.23	Yes	3.63	Yes
Metallurgy	90.96	4.77	Yes	3.01	Yes
Cant:Pos	3.73	4.77	No	3.01	Yes
Pos:Met	1.27	3.89	No	2.59	No
Met:Cant	0.75	3.89	No	2.59	No
<u>> 40 MGT:</u>					
Cant	3.86	6.23	No	3.63	Yes
Pos-in-Curve	57.97	6.23	Yes	3.63	Yes
Metallurgy	14.85	4.77	Yes	3.01	Yes
Cant:Pos	4.57	4.77	No	3.01	Yes
Pos:Met	0.96	3.89	No	2.59	No
Met:Cant	2.19	3.89	No	2.59	No

TABLE 8. GAGE FACE WEAR RESULTS FROM SECTION 13 (IN/MGT).

	Position-in-Curve					Average Figure of Merit
Metallurgy	A	B	C	D	Avg	
<40 MGT						
HH	0.0021	0.0017	0.0025	0.0021	0.0022	3.5
HiSi	0.0052	0.0049	0.0045	0.0043	0.0047	1.6
FHT	0.0038	0.0038	0.0034	0.0037	0.0037	2.1
Std	0.0063	0.0092	0.0094	0.0060	0.0077	1.0
Avg	0.0044	0.0049	0.0050	0.0046		
>40 MGT						
HH	0.0014	0.0012	0.0003	0.0010	0.0010	1.3
HiSi	0.0025	0.0001	0.0006	0.0014	0.0012	1.1
FHT	0.0020	-0.0001	0.0010	0.0012	0.0010	1.3
Std	0.0016	0.0010	0.0010	0.0016	0.0013	1.0
Avg	0.0019	0.0006	0.0007	0.0013		

A = Section 12 End
B,C = Middle
D = Section 14 End

TABLE 9. PRELIMINARY GAGE FACE WEAR RESULTS (IN/MGT) FROM THE SECOND SECTION 03 TESTS.

	Position				
Metallurgy	Section 02 End	Middle	Section 04 End	Average*	FM
Std	0.0006	0.0007	0.0005	0.0006	1
HH	0.0004	0.0003	0.0002	0.0003	2
CrMo	0.0001	0.0002	0.0002	0.0002	3
FHT	0.0005	0.0006	0.0005	0.0005	1.2
HiSi	0.0006	0.0007	0.0005	0.0006	1

* Rounded off.

COMPARISON WITH FIRST EXPERIMENT (AVERAGE OF ALL METALLURGIES IN LUBRICATED REGIME).

Location	First Experiment	Second Experiment
Section 02 End	0.0010-0.0014	0.00045
Middle	0.0016-0.0018	0.00049
Section 04 End	0.0005-0.0008	0.00037

TABLE 10. RESULTS OF STATISTICAL TESTS FOR SIGNIFICANCE OF OF THE SECTION 03 (SECOND EXPERIMENT) GAGE FACE WEAR RATES.

			Significance			
			At 99%		At 95%	
	Effect	Observed "F"	"F" Req'd	Yes/No?	"F" Req'd	Yes/No?
Without Tie Plate Cant Effect Removed	Metallurgy	71.496	9.15	Yes	4.53	Yes
	Pos-in-Curve	11.806	10.9	Yes	5.14	Yes
	Tie Plate Cant	3.791	10.9	No	5.14	No
With Tie Plate Cant Effect Removed	Metallurgy	42.115	7.01	Yes	3.84	Yes
	Pos-in-Curve	6.995	8.65	No	4.46	Yes

TABLE 11. TOTAL RAIL FAILURES IN METALLURGY TEST SECTIONS 03 AND 13 (BOTH RAILS).

	Plant Welds	Field Welds	Head Defects
First Experiment: (135 MGT)			
Section 03	44 (180)	44 (22)	2
Section 13	17 (64)	17 (10)	7
Second Experiment: (250 MGT)			
Section 03	10 (120)	12 (0)	15 (27/Mile[1])
Section 13	4 (48)	8 (0)	7 (10/Mile[2]) (30/Mile[1])

( ) Figure indicates number of welds initially installed.

[1] Figure indicates defect rate at 250 MGT per mile of track

[2] Defect rate adjusted to eliminate failures and rail length associated with "dirty" standard rail.

FAST Facility for Accelerated Service Testing

The Facility for Accelerated Service Testing (FAST) is located at the Transportation Test Center (TTC), Pueblo, Colorado. It is operated by the Federal Railroad Administration (FRA) of the U. S. Department of Transportation in cooperation with the Association of American Railroads (AAR) and the railroad companies and supply industry for the accelerated testing of track and mechanical components and systems.

The FAST Program is controlled by a policy committee composed of representatives from FRA, AAR, and the railroad industry. Its policies are implemented through Experiment Managers, each responsible for one or more experiments in a particular technical area. They report to the Manager of FAST Experiments, who requests the TTC to conduct FAST tests.

Operations are conducted by the TTC operations and maintenance contractor, Dynalectron Corporation, which is directed by FRA personnel in coordination with AAR staff in residence at the TTC.

The FAST Track is a specially constructed 4.8-mi* loop divided into 22 sections where specified combinations of track components and structures are installed for testing. It contains 2.2 mi of tangent, 0.4 mi of 3° curve, 0.3 mi of 4° curve, and 1.1 mi of 5° curve; the remaining 0.8 mi being transitional spirals.

Mechanical components are tested in the FAST consist, which is made up of 4-axle locomotives normally hauling a 75-car, 9,500-ton train. Cars are available from a pool of about 90 cars assigned to FAST. The majority are 100-ton hopper or gondola cars, and the remainder are 100-ton capacity tank cars and laden trailer-on-flat-cars.

Each test run begins in the afternoon, continues all night, and ends the next morning, five days a week. Each run makes approximately 120 laps of the FAST loop and produces approximately 1 million gross tons (MGT) on the track and about 600 mi on the cars, an accelerated service of about 10 times normal revenue operations in any given period of time.

To ensure uniform wear potential on track and mechanical components, direction of running is reversed each day, the whole consist is turned end-for-end every two days. Blocks of cars are shifted systematically within the consist on a 22-day cycle.

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*Metric Conversions:

1 mi = 1.6094 km
1 ton = 0.907 Mg
1 MGT = 0.907 MGMg

10/79

RPI

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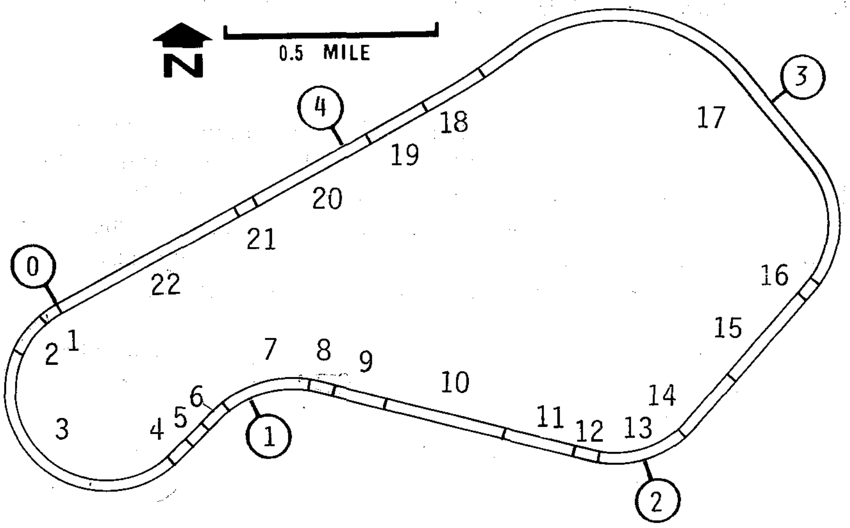
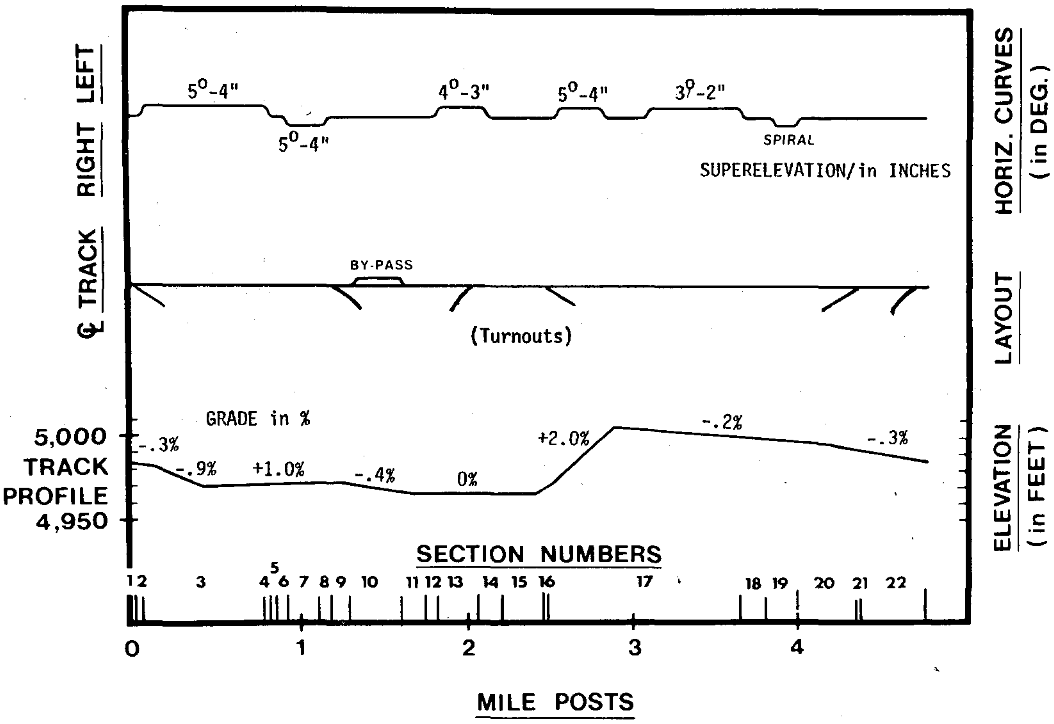


THE FAST TRACK



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