TECHNOLOGY DIGEST
Timely Technology Transfer

"Results of Rail Wear Tests at FAST"

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Summary

In a cooperative effort, the Association of American Railroads (AAR) and Federal Railroad Administration (FRA) are conducting rail tests at the Transportation Technology Center (TTC), Pueblo, Colorado. This effort is being done to quantify the effect of heavy axle loads on wear performance of different rail types.

Tests were conducted at the Facility for Accelerated Service Testing (FAST) on the lightly lubricated 5-degree curve in Section 07 and resulted in the following:

- Rail wear rates were initially high, but declined once the rail had "worn in."
- Wear results at the test location through 67 MGT show expected wear life of 240 MGT for standard rail (nominal hardness 300 Brinell) on the high rail of a lightly lubricated (near dry) curve. Expected wear life of head hardened rail ranges from 300 to 430 MGT.
- Head hardened rails resisted corrugation development much better than the standard rail. Corrugations in standard rail were as deep as 0.1 inch after 67 MGT; the head hardened rails have not developed any visible corrugations.
- Wear life of rail was increased up to a factor of 10 with lubrication.

The 5-degree test curve has 4 inches of superelevation. The FAST train operates at 40 mph, 6 mph over the balance speed (or 1.6 inches cant deficiency). High rail fatigue is very rare in this curve for three reasons: (1) the rail quickly wears to a conformal wheel/rail shape, which minimizes contact stresses, (2) the protective work hardening layer on dry worn rail has been shown to be deep (deeper than on lubricated rail), and (3) gage wear causes the rail to wear out before it fails in fatigue.

Suggested Distribution:
Operating Dept.
  ☐ Train Handling
Operating/Engineering Dept.
  ☐ Maintenance of Way
R & D/Test Dept.

Association of American Railroads
Research and Test Department

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INTRODUCTION AND CONCLUSIONS

Rails from worldwide manufacturers were donated to the FAST program to conduct the Rail Wear Test (see Table 1). All rails were head hardened, except the CF&I standard rail, which was installed as a control. One unusual head hardened rail was the NKK Damage Resistant, which has a softer rail head center designed to inhibit surface-fatigue spalling.

Hardness results, shown in the table, reflect the surface of the railhead center when it was new; i.e. it had not seen any traffic, and this in turn reflects any decarburation on the surface. Wear rates were calculated after 67 MGT of traffic had accumulated and are listed in inches per 1,000 MGT. For example, if the Sydney rail on the high side of the curve could be left in track for 1,000 MGT, it would be expected to wear laterally 1.67 inches and vertically 0.27 inch.

Wear Rates Decline with Accumulated Tonnage

All rails in test experienced high initial wear rates. In Exhibit 1, the relative width measurement results (measured at the 5/8 gaging point) of two sample rails, the NSC DH and the Sydney FHH, are plotted as a function of MGT. A best fit line was added

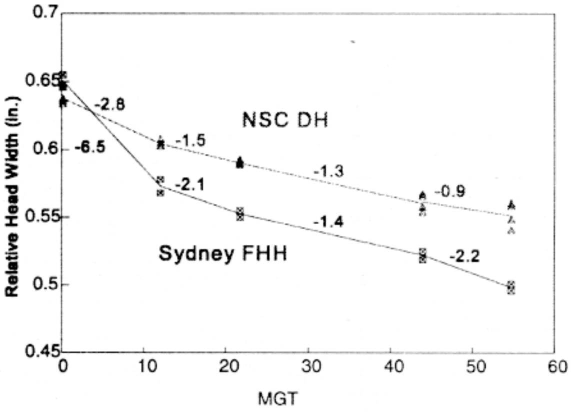

Exhibit 1. Wear Rates of NSC and Sydney Rails at Various Tonnages

Table 1. Donated Rails (as located in track)

RAIL MFG	RAIL SECTION	MFG PROCESS	Bhn	GAGE FACE WEAR RATE (IN/1,000 MGT)	HIGH RAIL WEAR RATE (IN/1,000 MGT)	LOW RAIL WEAR RATE (IN/1,000 MGT)
Sydney (FHH)	136-4 CN	Off-line "Fully" Head Hardened	311	1.67	0.27	0.31
Hayange (HH)	136 RE	Off-line Head Hardened	325	1.02	0.15	0.22
Thyssen (HH)	136-10	Off-line Head Hardened	323	1.50	0.27	0.19
CF&I (Std)	136-10	Control Cooled	272	2.10	0.78	0.48
NKK (THH)	136-10	In-line "Tough" Head Hardened	349	1.15	0.17	0.08
NKK (DR)	136-10	In-line Head Hardened "Damage Resistant"	315	1.17	0.21	0.15
NSC (DHH)	136-10	In-line "Deep" Head Hardened	352	1.26	0.18	0.11
Rodange (HH)	136-10*	In-line Head Hardened	285	1.52	0.28	0.29

***Modified 136-pound rail section**

between each measurement interval and the wear rate calculated from the slope of that line (inches/1,000MGT) is listed. The lateral wear rate of both rails decreased with tonnage up to at least 20 MGT. The Sydney rail had a lower initial hardness than the NSC, and the rails had different as-rolled profiles. Both of these factors influenced initial wear rates.

Test rails included four rolled sections. Contact geometry between FAST worn wheels varied with new rail profiles. To eliminate the effects of the initial profiles as a variable and to make resulting wear rates comparable, the wear rates listed in the table were calculated without the first two data points, i.e the data used for wear rate calculations were collected from 20 to 55 MGT.

Though the initial profiles of the various sections varied, they all wore to the same shape. This shape is reflected in worn profiles in Exhibit 2, which has overlays of the new rails and profiles collected after 47 MGT. This exhibit also shows the relative amount of wear each rail type encountered in 47 MGT.

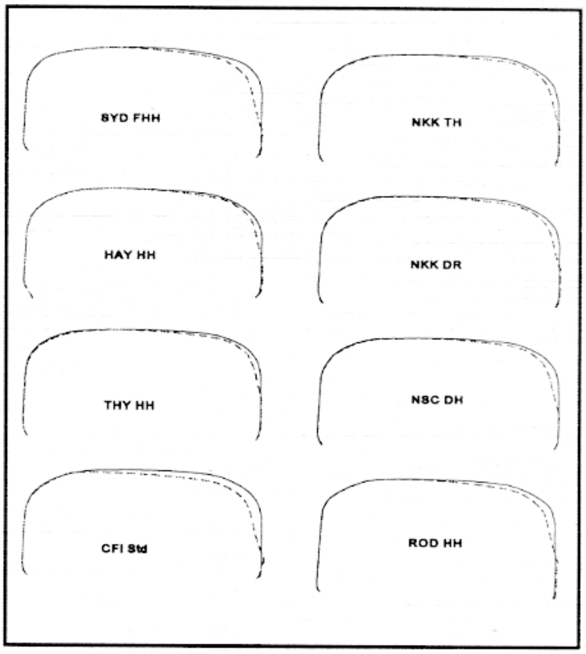

Exhibit 2. New Rail Sections Overlaid with Respective Worn Profiles (43.7)

Expected Rail Life

The wear rates listed in Table 1 can be used to predict the limit of rail life on this curve due to wear. Exhibit 3 illustrates the expected life of the test rails — the amount of tonnage a rail can be exposed to before accumulating ½ inch of wear at the location of the wear measurement. The ½-inch measurement was selected as it represents a considerable amount of wear, both in the gage face and head height directions.

In the test curve, gage wear will limit rail life on the high rail, and head height loss of either rail is not a critical issue. On the low rail, the control rail has a projected wear life of over 1,000 MGT and the NKK THH rail has a projected wear life of over 6,000 MGT. These lives are likely due to operation of the FAST train overbalance speed and lubrication of the low rail. Though the projected head height wear life of all rails is high, an implication here is that in any area where rail flattening is a concern, there is a benefit to be gained by selecting head hardened over standard rail. These projected lives assume no fatigue failures will develop.

These results can be contrasted with revenue service experience in areas where trains operate under the balance speed and head height loss of the low rail is a critical issue. In such instances, low rails may be replaced at 2 to 3 times the rate of high rails, and high rails are often transposed to low rails because they have encountered substantially gage wear with minimal height loss.

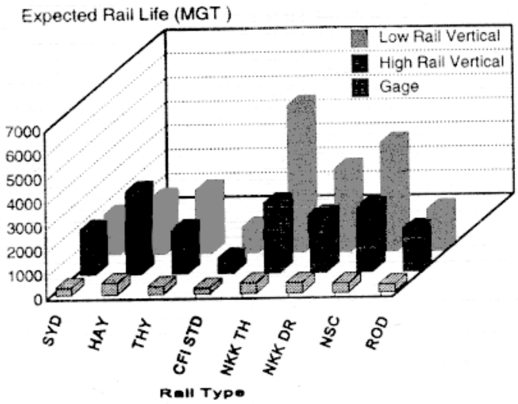

Exhibit 3. Expected Rail Life due to Gage, High Railhead Height, and Low Railhead Height Wear

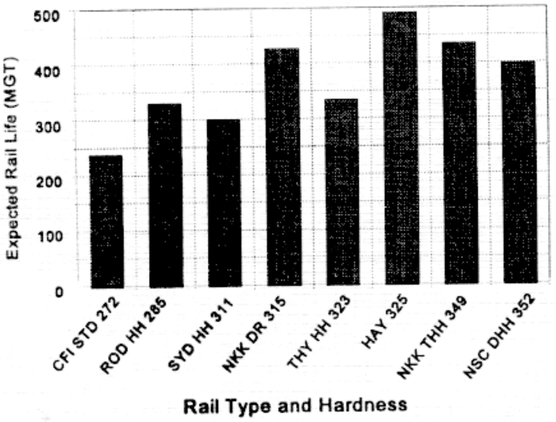

Exhibit 4. Expected Rail Life as Limited by Gage Wear

Increasing Hardness Increases Rail Life

The relationship between hardness and wear rate is shown in Exhibit 4 and illustrates expected gage wear life of each rail. The rails are arranged in order of increasing hardness from left to right. In general, as hardness increases, so does the expected life. The Hayange rail at 235 Bhn is expected to last almost 500 MGT. The control rail, with a hardness of 272 Bhn, is expected to last about 240 MGT.

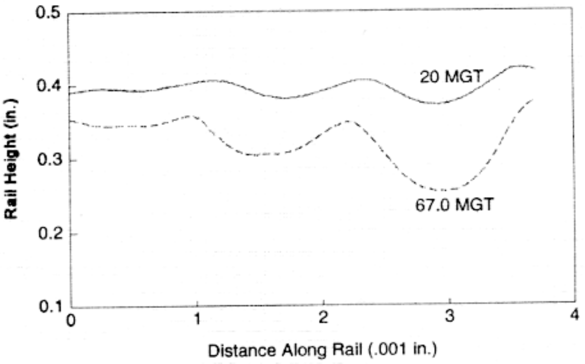

Exhibit 5. Corrugation Profiles in CF&I Standard Rail

Corrugations Develop in Standard Rail

Corrugations were observed in the control rail at 15 MGT. Measurements collected at 20 and 67 MGT, illustrated in Exhibit 5, depict how the corrugationsgrew with tonnage. By 67 MGT, corrugations were as deep as 1/10 inch. None of the head hardened rails had developed visible corrugations by 67 MGT.

Vertical force measurements collected on corrugated rail under 125-ton cars were as high as 95 kips in the trough of .070-inch corrugations. In the control rail, several surface fatigue defects (deep spalls) have developed in the troughs of corrugations, likely due to high dynamic vertical forces.

Lubrication Increases Rail Wear Life

Another test curve at FAST has identical geometry and operating conditions as the wear test curve. However, this curve is well lubricated with coefficient of friction readings: high rail top (.25-.30), high rail gage face (.15-.20), and top of low rail (.30-.40). This curve also contains NKK THH rail.

The life expected in the wear test is less than 500 MGT, while the same type of rail is expected to last almost 5,000 MGT in the well lubricated curve. This ten-fold increase in wear life would likely be even greater if the rail in the wear test were totally dry.

Contact Jon Hannafious at (719) 584-0682 with any questions or comments about this document.

A MORE DETAINED REPORT, WHICH MAY CONTAIN REVISED INFORMATION, WILL BE AVAILABLE AT A LATER DATE THROUGH THE DOCUMENTATION DISTRIBUTION CENTER, CHICAGO TECHNICAL CENTER, 3140 SO. FEDERAL STREET, CHICAGO, ILLINOIS 60616. PHONE: BETTY J. VAUGHAN (312) 808-5421. A REPORT LIST IS AVAILABLE UPON REQUEST.