Union Pacific’s Experience with High Carbon Rail

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Union Pacific began discussions with Nippon Steel in January 1995 about a high carbon rail they were developing. After reviewing laboratory wear and fatigue test results, we encouraged them to make a heat of rail and continue the due diligence testing. Physical properties of the rail were excellent, weldability by both flash butt and aluminothermic were identical to .80 carbon rail and fracture modes were ordinary. We installed a comparative wear test in the Blue Mountains of Oregon in November 1995.

This test compared the new high carbon rail (HE 370) to .80 carbon head hardened rails from Nippon, NKK, and Bethlehem. It was comprised of both high and low rails in five curves, one at 4.4 deg. three at 7 deg. and one at 8 deg. All were on 2% grade and handled about 50 MGT of bi-directional traffic annually. Wear measurements using a mini-prof, lubrication level, gage, elevation and surface condition evaluations were taken twice per year for four and a half years. None of the rails experienced fatigue failures. Wear resistance was the relevant factor in ranking of the participant rails.

HE 370 exhibited 12% less wear on the high rails and 15% less wear on the low rails than it’s closest competitor. It exhibited 30% less wear than the last ranking rail in the test. During the course of this test, Union Pacific moved our premium rail purchases from .80 to .90 carbon rails. We took our last delivery of .80 carbon rail from Nippon in June 2000. Union Pacific has over 1,400 track miles of high carbon head hardened rail today, and another 720 track miles scheduled for 2003. In tons, that equates to 330,400 today and 170,000 for 2003. Almost all of the rail received in 2000 and since is what we consider to be second generation high carbon rail (HE 400). This second generation rail is exhibiting the same type of improvement in regard to wear as HE 370 showed over .80 carbon rail; namely, a 15% reduction in wear over HE 370.

Union Pacific strongly encourages and supports the improvement and development of rail steels. Our criterion for new rail steels is clear and straightforward. They must be compatible to our existing rails. They must be weldable using our existing facilities, in track welders and aluminothermic weld kits. They must be invisible to our field forces. We continue to test rails from many manufacturers and let performance / life cycle cost guide our purchase decisions rather than initial price.

Today, we have a comparative test running on our Huntington Subdivision, North of Boise, Idaho. It sees the same tonnage and bi-directional traffic as our first test. It contains rail from six manufacturers. Nippon’s HE 400 is the control rail and is in every other position. The other participants are RMSM, PST, NKK, Hayange and Voest Alpine. The test had 100 MGT over it in July 02, and although gage face wear is only in the 1/8” to 3/16” range, there are already clear differences between the .90 C and .80 C rails. NKK, RMSM and Nippon have the higher carbon rails while Voest, PST and
Hayange have .80 carbon rails. The differences within the two groups are relatively small at this point but the difference between the groups is between 15 and 20%.

The curves on the Huntington test were set up to remain unground. At about 60 MGT, all of the low rails except HE 400 began to exhibit center spawling. This spawling had reached a depth of .030” to .040” at 100 MGT. Spawling of this depth would require four to six passes with the production grinders to remove. Since low rail wear was only around .030” on the high carbon rails at 100 MGT, grinding would have effectively doubled the low rail wear. This result was not totally unexpected. UP began using premium rail in tangent track several years ago. Our heavy haul corridors (over 50 MGT annually) make up about 30% of our system, we relay these lines with high carbon head hardened rail. In 2003 that will account for about 500 track miles. When the HE 400 rail was introduced, we began monitoring its performance, in tangent on our number 2 track West of Gibbon, Nebraska. This area handles 375 MGT annually, and No. 2 track handles about 240 MGT of that. We have observed a significant delay in and decrease of surface fatigue checking. In fact the checks we experience are only half as deep (.016”) as compared to .80 carbon rails. This allows complete removal with two grinder passes rather than four, and cuts frequency by 50% as well.

We will continue to monitor the Huntington curves and determine how long grinding can be delayed. It appears possible at this point to approach the surface fatigue resistance of a bainitic rail with a fully pearlitic rail and maintain all of our rail steel criteria.

We are currently planning a new wear test to begin late this fall. The area we have chosen is on the Mojave Sub. in Southern California. This line handles almost 80 MGT a year of bi-directional traffic through 10 degree curves on 2% grade. Some of you may have heard of the Tehachapies, we think it will be an excellent place to evaluate what may well be the third generation of High Carbon Rails.

In response to the railroad industry’s request for a more wear resistant rail, Rocky Mountain Steel Mills has developed a “High Carbon Pearlite” (HCP 410) rail. This deep head hardened rail metallurgy exhibits physical properties that will provide longer wearing rail under today’s demanding railroad service conditions. The high carbon deep
head hardened rail incorporates the use of increased carbon in the chemistry while still maintaining a fully pearlitic microstructure.

Deep Head Hardened rail (DHH) uses a chemistry that is basically the same as Standard Strength (SS) rail. DHH rail carbon level is between 0.78 and 0.82 wt.%, with an average of 0.80 wt.% carbon. The high carbon (HCP) deep head hardened rail uses a carbon level between 0.87 and 0.92 wt.% with an average of 0.90 wt.%. (Chart 1). The Manganese level for both the deep head hardened rail grades is the same and ranges from 0.90 to 1.00 wt.%, with an average of 0.93 wt.% (Chart 2). Silicon and chromium levels are also the same on both rail metallurgies, with a range of 0.27 to 0.34 wt.%, averaging 0.30 wt.%; and 0.20 to 0.25 wt.%, averaging 0.22 wt.% respectively (Charts 3 & 4).

A major attribute of the high carbon rail is its increased surface hardness as well as a significant increase in hardness at depth. Figure 1 shows a typical hardness traverse on head hardened rail, beginning from the near surface of the head to a depth of 40 mm. The hardness traverses are taken on centerline and gauge corners at increments that allow a hardness traverse to be plotted with enough resolution to highlight any sharp drops or deviations from the slope of the hardness traverse curve. Graph 1 shows a typical hardness traverse curve for high carbon deep
head hardened rail as compared to 0.80 wt.% carbon deep head hardened rail. Near
surface hardness for the high carbon rail
averages about 422 BHN, while the 0.80 wt.%
carbon rail averages a slightly more than 390 BHN. At ½” and 1” depth, the high carbon
rail achieves hardnesses of 405 BHN and 380 BHN respectively, while the 0.80 wt.%
carbon rail achieves hardnesses of 375 BHN and 350 BHN respectively.

The increase in hardness at depth is a very
important feature of high carbon rail. With the
increase in the popularity of the 141 AB
section, such increase in the depth of hardness
at both the ½” and 1 inch locations will allow
full material utilization of the heavier section.

Rail wear has a very strong correlation to the
hardness of the rail. In fact, Union Pacific has
documented an increase of around 30% in rail
life due to the increase in hardness.

Another positive attribute of the high carbon high strength rail is the upward shift in
strength as measured through tensile testing. For consistency reasons, AREMA, Chapter
4, defines the methodology for tensile testing.
Chart 5 displays the increase in Yield Strength
of 0.90 wt.% carbon rail as compared to 0.80
wt.% carbon rail. The high carbon rail has a
Yield Strength range of 129,000 psi to 143,500
psi with an average of 134,000 psi, while the
lower carbon rail has a Yield Strength range of
121,000 psi to 128,000 psi, with an average of
125,000 psi.
Chart 6 displays the increase in the Ultimate
Tensile Strength of 0.90 wt.% carbon rail as
compared to 0.80 wt.% carbon rail. The high
carbon rail has Ultimate Tensile Strength range
of 192,000 psi to 208,000 psi, with an average of 200,000 psi, while the lower carbon rail has an Ultimate Tensile Strength range of 182,000 psi to 187,500 psi, with an average of 184,500 psi.

The railroad industry can realize the benefit of a harder rail with more strength only if the ductility of the material is not compromised. One measurement of ductility is the percent of elongation in a tensile test. AREMA, Chapter 4 states that the minimum for ductility is 10% for high strength rail. Contemporary in-line heat treat technology can achieve this requirement, even with today’s high carbon rail metallurgies. Chart 7 displays the fact that there is basically no difference between the 0.80 wt.% Carbon rail and the high carbon rail. Both rails meet the minimum 10% requirement, with the averages being 11.7% and 11.45% respectively.

As can been seen from the physical properties of this high carbon pearlite metallurgy, conventional boundaries of pearlite are being pushed into areas once thought of as unachievable. It remains to be seen just how far these boundaries can be pushed in order to provide the North American railroad industry the best rail possible that can best withstand the industry’s ever increasing service demands.