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## Preliminary Performance of Wide-Gap Welds at Eastern Mega Site

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### Summary

Two types of wide gap weld (WGW) products are being tested in revenue service at the eastern mega site on a Norfolk Southern Railway (NS) located near Bluefield, West Virginia, since October 2005 and October 2006, respectively. As of December 31, 2008, one WGW product had accumulated 180 million gross tons (MGT), while the other had accumulated 122 MGT. In general, these welds (a total of 32) have performed well under the heavy axle load (HAL) operating environment. The following is a summary of their performance:

- Only one test weld was found to have an internal defect as a result of installation, and was replaced after the defect was detected by a handheld ultrasonic device following the installation. Subsequent periodic ultrasonic inspections to date have not identified any additional internal defects.
- Degradation of the longitudinal surface profile has been minimal to date for both the weld types.
- At the end of 2008, 31 percent of welds did not have any surface issues. The remaining welds, however, showed some plastic metal flow or minor gage corner shelling, but no periodic preventive grinding has been conducted on these test welds because they are located adjacent to the rail performance test curves where such grinding has not been allowed for test purposes. Similar plastic metal flow and shelling were also observed on similar welds installed at the Facility for Accelerated Service Testing (FAST), although these occurrences came much earlier at FAST, partially due to higher axle load operations.
- Measurements indicated typical work hardening effects on all test welds, meaning that hardness of welds increased with HAL traffic. In general, test weld values were lower than 400 hardness Brinell, slightly lower than those of the head-hardened premium rails.

WGWs were developed as an alternative repair process to the conventional plug and weld procedure. The wider gaps enable the use of a single weld to repair railhead defects. Welds or rails with defects or transverse breaks limited in the longitudinal direction to 2.75 inches in length can be repaired by the use of a single WGW, reducing labor and out of service time for the track.

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**INTRODUCTION**

WGWs are thermite welds that utilize a wider weld gap than standard thermite welds, 2.75 inches as opposed to 1 inch. Weld gap is the distance between the rail ends prior to welding. WGWs were developed as a way to make repairs to rails or welds. Railhead and weld defects not exceeding 2.75 inches longitudinally in the rail can be repaired using a single WGW thereby eliminating the need for a rail plug and an additional field weld. The same repair method can also be used for full-section transverse rail and weld breaks not exceeding 2.75 inches longitudinally in the rail. WGWs have also been used as compensation welds to join rails of different sections. With a WGW the transition between rail sections occurs over the weld's 2.75-inch gap, whereas in a standard weld the transition occurs over a 1-inch gap. The additional potential benefit of using a WGW is that it may cause less change in rail neutral temperature or longitudinal rail stress when the amount of rail pulling is reduced as compared to standard rail welding methods.

Transportation Technology Center, Inc., (TTCI) has tested WGWs in the laboratory and at FAST.<sup>1-4</sup> Based on the satisfactory results from those tests, TTCI recommended that WGWs be formally tested in revenue service under HAL operating conditions at the eastern mega site near Bluefield, West Virginia.

The eastern mega site was established in 2004 on a NS Railway heavy haul coal line as part of a joint research program funded by the Association of American Railroads and the Federal Railroad Administration and hosted by NS. The program was established to investigate the effects of HAL operations on track components and to assess new and improved products and practices with the aim of mitigating the effects of HAL traffic on the track infrastructure.<sup>5</sup> As part of this effort, a WGW test was established to investigate weld performance under HAL revenue service conditions.

**MEGA SITE TESTING**

A total of 32 WGWs, 16 welds each from Orgo-Thermit, Inc.

and Railtech Boutet, Inc., were installed in track at the eastern mega site. The Orgo WGWs were installed in October 2005, and the Railtech WGWs were installed one year later in October 2006. The Orgo WGWs were made using two-piece kits and the Railtech WGWs were made using three-piece kits. The welds were installed in the spirals adjacent to the curves used in the rail performance test, and as a result, the welds are located in a no-rail-grinding zone. The welds were staggered and alternated between high and low rail to minimize preferential effects due to the location in the spirals on any one weld manufacturer's product. All welds were made in 141RE section rail. Figure 1 illustrates the layout of the test (curvatures for these curves are either 6.8 degrees or 10 degrees). The welds currently receive approximately 53 MGT of traffic per year.

After installation, each weld was scanned ultrasonically for defects. One weld was found to have a defect in the weld collar, just under the railhead. The weld was removed, a rail plug was installed, and another test weld was installed in its place. The NS metallurgical laboratory in Roanoke, Virginia, sectioned and examined the removed weld. The weld was found to contain a gas pore in the weld collar that was approximately 1/8-inch in diameter and 1/2-inch long. This type of defect is not unusual and may occur in thermite welds regardless of weld gap size.

TTCI took initial hardness measurements and longitudinal profiles after several days of operation to allow for development of a running band on the weld. Surface hardness values were measured at five locations for each weld. These included both parent rails at approximately 12 inches on each side of the weld, both heat affected zones (HAZ) adjacent to the weld, and the weld centerline. Weld profiles were taken in the longitudinal direction in the center of the running band on the head of the weld and rail using a profilometer and fixture adapted for the purpose. Visual inspections and subsequent measurements have been conducted on a semi-annual basis to monitor and document the performance of the test welds. NS has provided periodic manual ultrasonic scanning to monitor the welds for the development of internal defects.

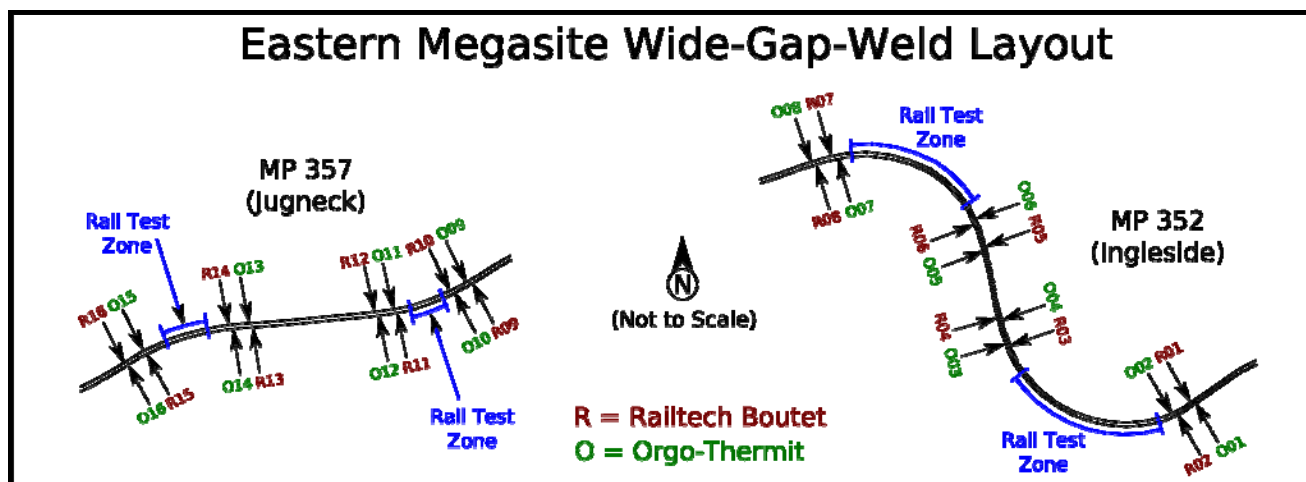
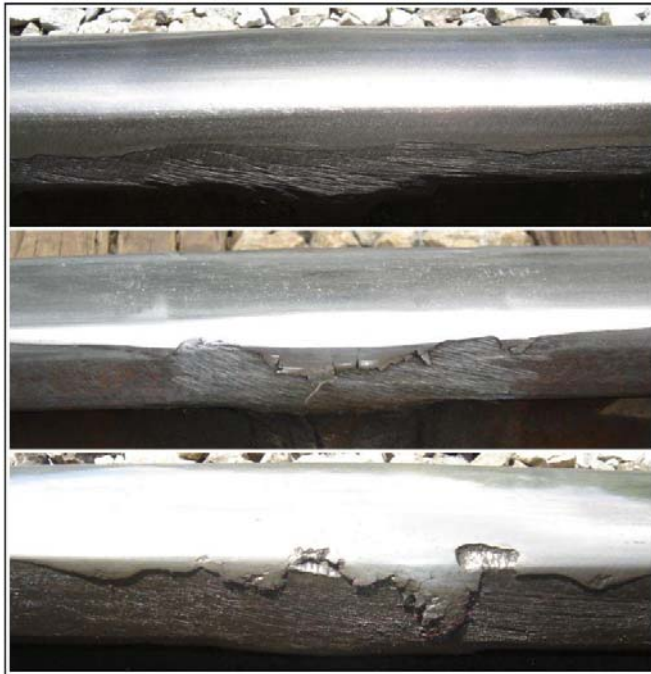


Figure 1. Mega Site Wide-Gap-Weld Test Layout  
Welds are located in the spirals adjacent to the rail test curves.

**PERFORMANCE RESULTS**

As of December 31, 2008, the Orgo-Thermit welds have accumulated 180 MGT, and the Railtech Boutet welds have accumulated 122 MGT. Overall, the welds are visually in good condition with the exception of some plastic flow and minor shelling on the gage corners on some welds. Figure 2 shows several welds that represent various overall weld conditions. In this figure, the top picture shows the typical good condition of a test weld, the middle picture shows a weld with some plastic flow, and the bottom picture shows a weld with some minor shelling.



**Figure 2. Sampling of Weld Conditions: (Top) Good Weld Condition; (Middle) Plastic Flow on Gage Corner; (Bottom) Plastic Flow and Minor Shelling on Gage Corner.**

In a typical HAL revenue service operation, welds often receive the benefits of periodic preventative rail grinding maintenance. The welds in this test, however, have not received any preventative rail grinding because they are located in a no-rail-grinding zone due to the adjacent rail performance tests.

Whereas this no-grinding situation does not necessarily reflect typical revenue service operating conditions, it does allow for observation of accelerated weld degradation and for comparison with the performance of similar WGWs at FAST. In general, the performance of the WGWs at the mega site is similar to the performance of those at FAST with regard to plastic flow and shelling, with the exception that the WGWs at FAST tend to degrade quicker under the 39-ton axle loads operating conditions at FAST. At FAST, WGWs in 5-degree curves begin to degrade in a similar manner, although to a greater magnitude at approximately 55 MGT, as compared to greater than 100 MGT at the eastern mega site.

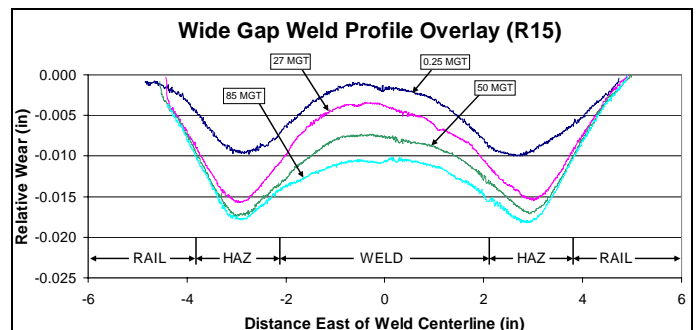
The WGWs at the eastern mega site will be ground with a handheld grinder in the spring of 2009 to remove plastic flow and minor shelling.

Table 1 summarizes conditions for each of the welds and shows 69 percent of the Orgo-Thermit welds and 63 percent of the Railtech Boutet welds were experiencing some degradation in the form of plastic metal flow or both plastic metal flow and minor shelling. On the high rail welds in the 10-degree curves, 100 percent of the shelling for both products is occurring.

**Table 1. Summary of Weld Conditions**

	Orgo-Thermit		Railtech-Boutet	
MGT as of December 2008	180		122	
Number of Welds With No Plastic Flow or Shelling	5 of 16		6 of 16	
	High	Low	High	Low
	0	5	2	4
Number of Welds With Only Plastic Flow	7 of 16		9 of 16	
	High	Low	High	Low
	4	3	5	4
Number of Welds with Shelling (also plastic flow)	4 of 16		1 of 16	
	High	Low	High	Low
	4	0	1	0

TTCI collected longitudinal profiles for the welds at different MGT levels and then plotted the profiles. The overlaid plots for the different tonnages were used to examine weld longitudinal surface degradation trends. Figure 3 shows an example profile overlay for Railtech weld R15. This type of overlay places the profiles based on the assumption of zero head wear in the parent rail. As a result, the overlays highlight wear rates of weld relative to the parent rail by the distance between the successive profiles. As shown, the profiles for the test welds are consistent with profiles typical of thermite welds, in which the softer HAZ wears or batters quickest followed by wear/batter of the weld metal. The maximum wear measured was less than 0.02 inches, currently with no observed strong correlation between wear and weld condition. Note that the scales in Figure 3 are different between horizontal and vertical axes.



**Figure 3. Weld Profile Overlay (Weld regions are approximate)**

Weld surface hardness values were also measured at various MGT levels and analyzed to determine any trends. Figure 4 shows a summary of hardness test results obtained at various MGT levels for both weld products (for those welds located in the high rails). As shown, the welds experienced typical work hardening in the HAZ and at the weld centerline, meaning that surface hardness of the test welds increased with traffic. In addition, the hardness values measured at the centerline were slightly lower than those of the parent rails, which are head-hardened premium rails. As expected, the hardness results measured in the HAZ were lower than those measured for both the parent rails and the welds.

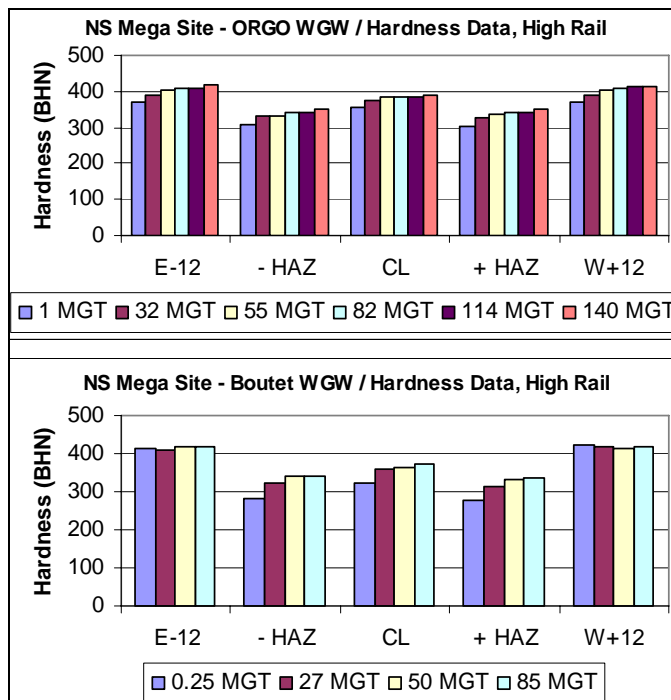


Figure 4. Average Weld Hardness for High Rail Wide-Gap Welds. (Top) Orgo-Thermite. (Bottom) Railtech Boutet.

## CONCLUSIONS

As of December 31, 2008, the WGWs installed at the eastern mega site had performed well in the HAL operating environment. The following is a summary of their performance:

- Only one test weld was found to have an internal defect as a result of installation, and was replaced after the defect was detected by a handheld ultrasonic device following the installation. Subsequent periodic ultrasonic inspections to date have not identified any additional internal defects.

- Degradation of the longitudinal surface profile of both weld products has been insignificant to date.
- At the end of 2008, 31 percent of welds did not have any surface issues. The remaining welds have shown some plastic metal flow or minor gage corner shelling; however, no periodic preventive grinding has been conducted on these test welds because they are located adjacent to the rail performance test curves where such grinding has not been allowed for test purposes. Similar plastic metal flow and shelling were also observed on similar WGWs at FAST, although their occurrences came much earlier, partially due to heavier axle load operating conditions at FAST.
- Measurements indicated typical work hardening effects of wheel/rail interaction on all test welds, meaning that hardness of the welds increased with HAL traffic. In general, test weld values were less than 400 hardness Brinell, slightly lower than those of the head-hardened premium rails. As expected, the HAZs have hardness values lower than either the parent rails or the welds.

## REFERENCES

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