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## Effects of Track Gage Variation on Rail Performance: Results at 187 MGT

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### Key Findings:

- Low rail in the narrow gage zone shows a statistically significant increase in overall wear and vertical wear compared to the low rail in the wide gage zone. High rail in both narrow and wide gage zones have similar wear.
- Rolling contact fatigue (RCF) is confined to a narrow band on the center of the top of the low rail in the narrow gage zone and has not significantly changed since its initiation at approximately 50 MGT. RCF started developing close to the field corner in the form of deep sporadic spalls on the top of the low rail in the wide gage zone and has progressed to form further spalls over time.
- High rail RCF is mild and similar in severity throughout the narrow and wide gage zones.

Since 2016, [Transportation Technology Center, Inc. \(TTCI\)](https://www.ttci.org/) has been studying the influence of track gage variation on rail performance in a 5-degree curve of the High Tonnage Loop (HTL) at the Facility for Accelerated Service Testing (FAST), Pueblo, CO. TTCI chose a type of intermediate strength (IS) rail with an approximate hardness of 350 Brinell hardness number (BHN) from a rail manufacturer for this test. Under the guidance of the members of the rail technical advisory group, two different track gages were chosen: 56.25 inches (narrow) and 57 inches (wide). Each test zone measured approximately 376 feet with 40 feet of transition zone between the two test zones. Current FRA regulations for Class 3 and Class 4 tracks limit track gage to 56 inches minimum and 57.5 inches maximum. The nominal track gage for the railroad industry is 56.5 inches. The aim of this test is to analyze the effects of a narrow gage (56.25 inches) and a wide gage (57 inches) on rail wear and RCF performance.

Preventative maintenance grinding was used to control RCF, with better results observed on the low rail of the narrow gage zone than in the wide gage zone, as indicated by the absence of deep sporadic spalls in the narrow gage zone. Gage widening was observed in both narrow and wide gage test zones with the maximum change happening between 0 MGT and 53 MGT.

Section 3 of the HTL is a 5-degree curve with 4 inches of superelevation equipped with gage face lubrication on the high rail. The low rail is not directly lubricated throughout the curve. The FAST train, with its mostly 39-ton axle loads, runs approximately the same number of laps in both clockwise and counter-clockwise directions at an average speed of 40 mph, compared to a balance speed of 34 mph. A Class I railroad donated two 792-foot strings of continuously welded IS rail of approximately 350 BHN. Each string had ten 80-foot rails of the same IS type welded to one another by an electric flash butt (EFB) welding process. Only one rail type was selected for this test to avoid the influence of variable rail metallurgy and rail properties on rail performance.

## TEST LAYOUT

TTCI based the test layout on multiple NUCARS® simulations that analyzed whether wheel-rail forces and vehicle responses were within criteria from Chapter 11 of AAR's *Manual of Standards and Recommended Practices*.<sup>1</sup> Since the rest of the HTL is designed to be at nominal gage of 56.5 inches, smooth transitioning from narrow or wide gage to nominal gage is critical for safe train operations at FAST. The layout of the test is shown in Figure 1.

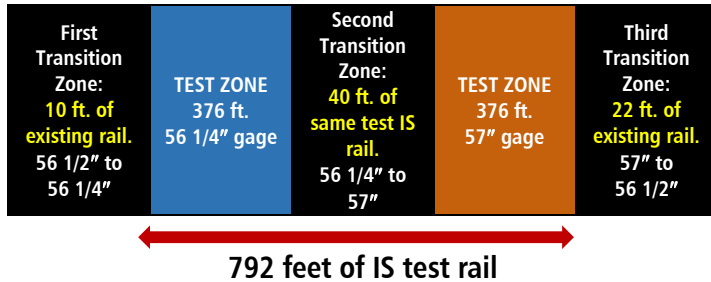


Figure 1. Layout of the test with test and transition gage zones (zone lengths are not to scale)

TTCI selected three transition zones with the critical zone being the middle (or second) transition from 56.25 inches to 57 inches. TTCI conducted NUCARS® simulations to find the minimum length of this transition zone required for safe vehicle performance according to Chapter 11 criteria.<sup>1</sup> Parameters analyzed in NUCARS® included maximum car body roll angle, vertical wheel load, vertical suspension deflection, vertical acceleration, lateral acceleration, wheel lateral/vertical (L/V) ratio, truck side L/V ratio and axle L/V ratio. Each parameter was analyzed for both counter-clockwise and clockwise train movements at speeds of 10, 20, 30, and 40 mph. The simulated minimum vertical wheel loads of the cars, expressed as a percentage of the static vertical wheel loads, were well above the Chapter 11 minimum limit and were similar for both directions (see Figure 2). All other simulation parameters not shown here were well within the recommended limits.

Based on the NUCARS® simulations, the transition from 56.25 inches to 56.5 inches was designed to be spread over 10 feet of existing rail while the transition from 57 inches to 56.5 inches was designed to be spread over 22 feet of existing rail. The middle transition from 56.25 inches to 57 inches was designed to spread over 40 feet.

\*NUCARS® is a registered trademark of Transportation Technology Center, Inc.

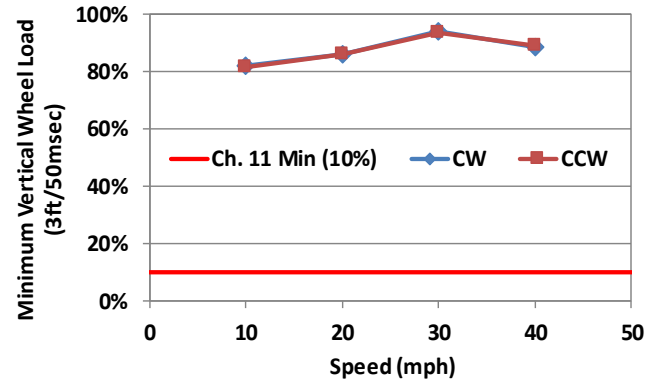


Figure 2. Minimum vertical wheel loads from NUCARS® simulations for test design

## WEAR ANALYSIS

Researchers measured rail profiles at five locations evenly spaced at 6-foot intervals on each 40-foot piece of rail. Fifty locations with 25 each on the high and low rails were selected individually for both narrow and wide gage zones. In the 40 feet of middle transition zone, 12 locations were selected on both the high and low rails for measurement purposes. A total of 124 locations with 100 locations in the narrow and wide gage zones were marked at the beginning of the test. Earlier tests of intermediate strength rails in the same 5-degree curve had shown preventative maintenance grinding as an important contributor in inhibiting shell initiation. To remove surface cracks and inhibit shell formation, this test was planned to be ground at 60-70 MGT intervals. Data was collected at regular intervals before and after grinding along with track gage measurements.

Figure 3 shows the wear pattern of the high and low rails of the entire test zone at 187 MGT.

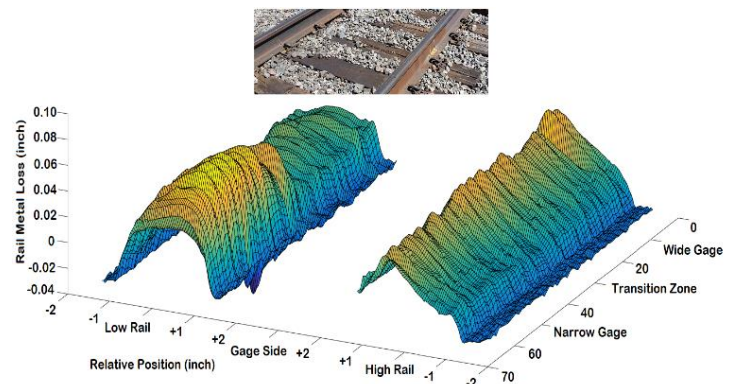


Figure 3. Wear patterns of high and low rails at 187 MGT

The z-axis of this wear plot is corresponding to the way the rails are laid in track (inset). A positive number in the x-axis represents the gage side of the rail with zero being at the

central longitudinal y-axis on the top of the rail. Although wear contributes to metal loss, this plot is shown in a manner where positive value along z-axis represents depth of wear. The high rail has gradually changed, but almost similar wear amounts from the narrow to the wide gage zones with more wear towards the gage corner. The low rail has a difference in wear from the narrow gage zone to the wide gage zone with higher wear in the narrow gage zone. The wear on the low rail between the gage corner and the center of the top of the rail surface gradually reduces as the track gage transitions from narrow to wide.

Figure 4 shows a direct comparison of the vertical loss of the high and low rails of the narrow and wide gage zones. While the vertical loss on the high rail is slightly higher in the wide gage zone than the narrow gage zone, vertical loss on the low rail has a bigger difference between the two gage zones. Using a two-sample T-test, the mean vertical loss of the low rail was greater for the narrow gage zone by 0.03 inch using a 0.05 level of statistical significance at 187 MGT.

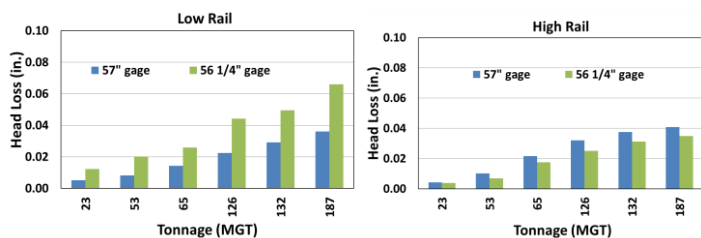


Figure 4. Comparison of vertical loss or vertical loss of high rails (left) and low rails (right) between the narrow and wide gage zones until 187 MGT

### ROLLING CONTACT FATIGUE (RCF) PERFORMANCE

TTCI monitored RCF on both high and low rails in narrow and wide gage zones since the test began. RCF started appearing in the center band of the top of low rail in the narrow gage zone after accumulating approximately 50 MGT. The low rail in the wide gage zone did not have any spalling or RCF until approximately 100 MGT. The RCF observed in the low rail of the narrow gage zone has been concentrated as a narrow band at the center and has not changed significantly over time (see Figures 5a and b). However, the low rail in the wide gage zone started with sporadic but deep spalling close to the field corner and has slowly progressed to generate more spalls over time (see Figures 6a and b).

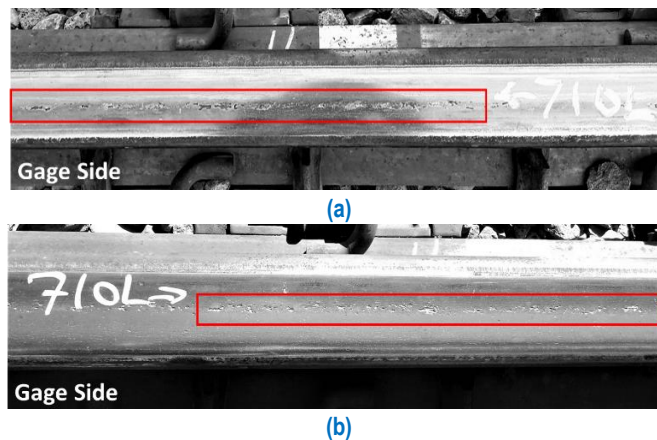


Figure 5. Location on low rail in narrow gage zone showing narrow RCF band at 96 MGT (a) and at 187 MGT (b) with one preventative grinding done in between

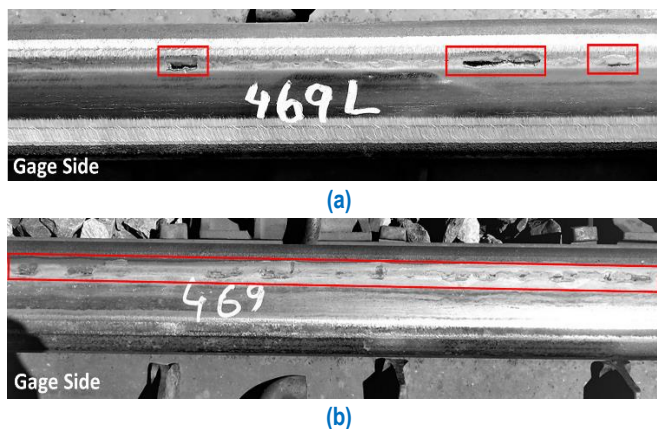


Figure 6. Location on low rail in wide gage zone showing sporadic spalls existing at 127 MGT after grinding (a) and increased number of spalls at 187 MGT before grinding (b)

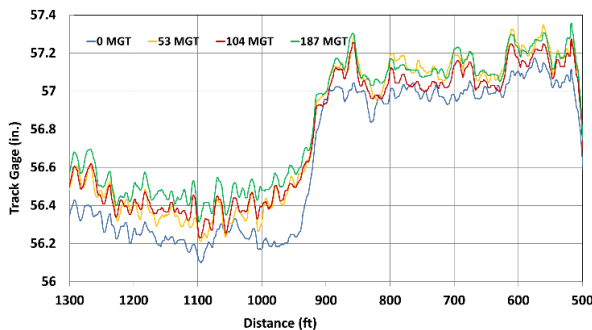
Preventative maintenance grinding was performed twice until 187 MGT: once at approximately 53 MGT and then at again at approximately 128 MGT. A third grinding will be performed at approximately 190 MGT. In all three cases, grinding was focused on the removal of surface RCF and spalls from the low rail. Light grinding was performed on the high rail and included mild gage corner relief. While grinding has been successful to remove most of the RCF in the narrow gage zone, it did not completely remove the deeper spalls observed in the wide gage zone as evident in Figure 6a. It should be noted that grinding was done with the same number of passes making equivalent metal removals from the entire low rail of both narrow and wide gage zones. High rail RCF has been mild and similar across both wide and narrow gage zones since it was first observed at around 100 MGT. The high rail in this 5-degree curve benefits from gage face lubrication while the low rail is not directly lubricated. The low rail also had more grinding

passes than the high rail, and the metal loss due to grinding (along with wear) contributed, to the overall vertical loss of the rails shown in Figure 4. Until 132 MGT, the two grinding operations have approximately contributed a total of 0.005 inch to the overall metal loss of the low rail.

TTCI is currently analysing wheel-rail contact stresses along with curving forces of the train's locomotives and cars currently to understand the difference in RCF and spalling on the low rail between the two gage zones. A future *Technology Digest* will detail this analysis.

### GAGE WIDENING

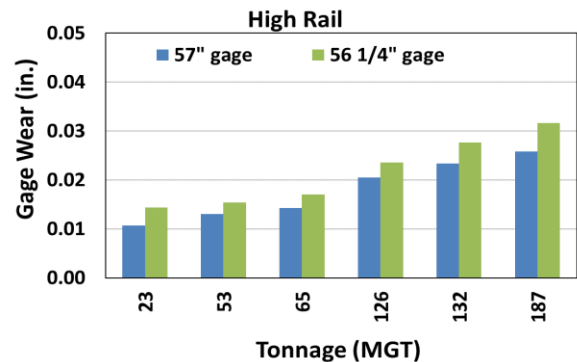
Instantaneous track gage was measured in the entire test zone during rail profile measurements. Figure 7 shows how the track gage changed over tonnage up to 187 MGT.



**Figure 7. Gage widening observed throughout the test zone at different tonnage intervals.**

Both the narrow and wide gage zones have experienced gage widening. While the narrow zone has mostly widened to the nominal gage of 56.5 inches, the wide zone has increased up to 57.2 inches. The wide gage zone also was found to be consistent over the length of 376 feet of test zone since the start of the test, while the narrow gage zone has been found to vary from 56.25 inches to 56.4 inches for approximately the last 100 feet of the test zone. It is important to note that the rate of gage widening was significant between 0 MGT and 53 MGT and has slowly reduced. A small contributing factor to gage widening was the gage wear on the high rails of both narrow and wide gage zones (Figure 8) with mean gage wear being higher on the narrow gage than wide gage using a 0.05 level of statistical significance. The flangeway clearance of wheelsets in curved track decreases as the gage of the track decreases. The reduction in flangeway clearance of the narrow gage test zone restricts the ability of wheelsets to shift laterally and develop the necessary rolling radius difference to steer

through the curve. This restriction results in harder flanging and higher lateral forces.



**Figure 8. Gage wear on high rail in both gage zones**

### CONCLUSIONS

A test was started in a 5-degree curve of the HTL at FAST where the influence of two different track gages (56.25 and 57 inches) on rail performance are being analyzed. TTCI conducted NUCARS® simulations as a part of designing the test to ensure safe train operating conditions. Results up to 187 MGT show wear differences primarily on the low rail for the narrow and wide gage zones along with surface RCF development. Preventative maintenance grinding helped control RCF on the low rail of the narrow gage zone. However, deep sporadic spalls were observed on the same low rail of the wide gage zone and could not be eliminated completely by grinding. Both test zones experienced gage widening since the start of the test.

### References

1. *AAR Manual of Standards and Recommended Practices*, 2007. M-1001, Chapter 11, "Service Worthiness and Analyses for New Freight Cars." Association of American Railroads. Washington, DC.
2. Banerjee, Ananyo and Joseph LoPresti. March 2017. "Intermediate Strength Rail Test: Wear and Defect Analysis." *Technology Digest* TD-17-005. AAR/TTCI, Pueblo, CO.

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