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## Initiation of the Revenue Service Test of High Performance Wheels

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### Summary

Transportation Technology Center, Inc. (TTCI) is evaluating eight types of high performance wheels in a revenue service Union Pacific coal train as part of the Association of American Railroads' (AAR) Strategic Research Initiatives (SRI) Program to prevent wheel failures.

The goal of this SRI is to develop and test high performance wheels to improve the wear and fatigue performance. AAR/TTCI initiated a revenue service test August 21 to quantify the benefits of eight types of high performance wheels paired with composition brake shoes in comparison to AAR Class C wheels paired with composition brake shoes and two types of tread conditioning brake shoes.

None of the testing completed to date has indicated any safety concerns related to the high performance wheels.<sup>1,2,3,4,5</sup> The third phase of testing for the high performance wheels is the revenue service test and is discussed here. The intended test duration is approximately three years to allow sufficient time for a statistically significant number of wheelset removals. Data from wayside detectors will be used to monitor performance of the wheels and cars in the test train. Reliability engineering methods, including Weibull analysis and Analysis of Variance will be used to compare the wheel life of different wheel and brake shoe combinations.

Prior to initiation of the revenue service test, safety of the high performance wheels was verified through laboratory tests and controlled-environment tests conducted at the Transportation Technology Center, Pueblo, Colorado. Wheel/rail forces produced by cars in the test train were recorded and evaluated to ensure that cars with poor curving performance would not unduly influence the wheel life results of any particular wheel and brake shoe combination.

Griffin, Lucchini, OneSteel, Standard Steel, Sumitomo, and Valdunes donated high performance wheels for this project. OneSteel is participating with two steel compositions. The SRI steel wheel is also being tested as part of this program.



**INTRODUCTION**

As part of the AAR’s SRI program to prevent wheel failures, a revenue service test has been initiated on eight types of high performance wheels. The goal of this project is to develop and demonstrate the benefits of high performance wheel steels, specifically focusing on improvements in resistance to wear and fatigue. The revenue service test began August 21 and is being conducted to quantify the benefits of each type of high performance wheel in comparison to the current standard AAR Class C wheels.

Griffin, Lucchini, OneSteel, Standard Steel, Sumitomo, and Valdunes donated high performance wheels for this project. OneSteel is participating with two steel compositions. TTCI’s high performance wheel, known as the SRI wheel, is also being tested. With the exception of the SRI wheel, a generic naming convention will be used to identify each manufacturer’s wheels.

**BACKGROUND**

The testing of the high performance wheels consists of three overlapping phases. First, laboratory testing was conducted on each wheel steel including measurements of mechanical properties, microcleanliness, and residual stresses.<sup>1,2,3</sup> Next, the wheels were installed in loaded cars at TTC and subjected to a drag braking test and are currently involved in a durability test at the Facility for Accelerated Service Testing.<sup>4,5</sup> None of the testing completed to date has indicated any safety concerns related to the high performance wheels. The third phase of testing for the high performance wheels is the revenue service test.

**TEST TRAIN**

The revenue service train used to test the high performance wheels is composed of 105 steel hopper cars owned by the Union Pacific (UP). The light weight of these cars is in the range of 61,000 pounds to 65,000 pounds and the cars are rated for a gross rail load of 286,000 pounds. Build dates on the cars range from 1979 through 1983. Immediately prior to the test, the cars went through a rebuild program consisting of a truck upgrade to AAR M-976 qualified Barber S2-HD-9C split wedge trucks with primary suspension shear pads and D5 spring nest. The height of the sides and ends of the cars were extended to increase the cubic capacity to 4,000 cubic feet. The cars were equipped with polymer center-bowl liners and long travel constant-contact side bearings with a nominal 6,000-pound preload. The brake arrangement is a body-mounted rod-through-bolster design with the dead levers connected to the bolsters. Slope sheet empty/load devices provide a 50 percent reduction in brake cylinder pressure when the cars are empty.

High friction composition brake shoes were installed on all cars equipped with the high performance wheels and 16 control cars with AAR Class C wheels. An additional 18 cars are equipped with AAR Class C wheels and one of two types of tread conditioning shoes (called TC-A and TC-B in this report). This was done to be able to compare the life of high performance wheels not only to that of AAR Class C wheels

with composition brake shoes, but also to the wheel life of AAR Class C wheels with tread conditioning brake shoes. Tread conditioning brake shoes were not paired with any of the high performance wheels for two reasons: (1) to maximize the sample size of the high performance wheels paired with composition brake shoes and (2) to minimize the test duration required to experience a significant number of wheelset removals. Stencils on each test car indicate which shoe type to apply when the shoes are in need of replacement.

The remaining cars in the train were rebuilt prior to 2009 and do not have new wheels and therefore will not be considered part of the test. The high performance wheels are intended to be resistant to wheel fatigue and shelling damage, but may not provide significant benefits in terms of resistance to slid flats and spalling. In an effort to minimize the potential for misleading data due to hand-brake related wheel slides, the cars with older wheels were placed at either end of the train where hand-brake applications would be most likely to occur.

Cars with wheels involved in the test have been stenciled to indicate that the wheels are part of a test and instructing the shop personnel to call a UP helpdesk phone number before removing the wheelsets. The UP helpdesk will provide special wheelset handling instructions in order to save the test wheelsets for inspection and also to avoid sending the high performance wheels to a wheel shop for truing and reapplication under a nontest car.

Table 1 contains a count of the wheelsets and brake shoes in the test train. Table 2 shows the car locations within the train. Figure 1 shows statistical data describing the relative placement in the train of each type of wheel and brake shoe combination. The mean and standard deviation of car position within the train are similar for all wheel and brake shoe combinations. Because not all types of wheelsets were available in multiples of four, some cars were equipped with more than one type of wheel. For example, in Table 2, car position 50 appears next to “AAR Class C, Comp Shoes,” “Wheel 1, Comp Shoes” and “SRI Wheel, Comp Shoes.” Wheel types were never mixed within a wheelset.

**Table 1. Count of Test Wheelsets**

Wheel Type	Brake Shoe Type	Wheelset Count
Older Wheels Excluded from Test	Mixed	89*
AAR Class C	Composition	54
AAR Class C	Tread Conditioning “A”	40
AAR Class C	Tread Conditioning “B”	32
Wheel 1	Composition	29
Wheel 2	Composition	28
Wheel 3	Composition	29
Wheel 4	Composition	30
Wheel 5	Composition	25
Wheel 6	Composition	26
Wheel 7	Composition	25
SRI Wheel	Composition	13
Total:		420

\* includes 22 cars not rebuilt in 2009 plus 1 wheelset in a recently rebuilt car with visible but noncondemnable tread damage.

Table 2. Car Distribution in Train

Wheel and Brake Shoe Type	Car Position in Train (1 = first car, 105 = last car)
Older Wheels Excluded from Test	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 57, 95, 96, 97, 98, 99, 100, 101, 102, 103, 104, 105
AAR Class C, Comp Shoes	13, 25, 31, 33, 35, 43, 47, 50, 57, 61, 63, 72, 81, 84, 88, 94
AAR Class C, TC-A Shoes	12, 16, 26, 36, 48, 58, 59, 70, 82, 93
AAR Class C, TC-B Shoes	14, 24, 37, 46, 60, 71, 80, 92
Wheel 1, Comp Shoes	19, 34, 44, 49, 50, 65, 74, 87
Wheel 2, Comp Shoes	18, 29, 40, 53, 66, 73, 89
Wheel 3, Comp Shoes	22, 32, 33, 42, 52, 69, 76, 91
Wheel 4, Comp Shoes	23, 30, 41, 43, 51, 68, 75, 90
Wheel 5, Comp Shoes	17, 31, 45, 56, 62, 77, 85
Wheel 6, Comp Shoes	15, 28, 39, 55, 64, 79, 84
Wheel 7, Comp Shoes	20, 27, 38, 54, 63, 78, 86
SRI Wheel, Comp Shoes	21, 50, 67, 83

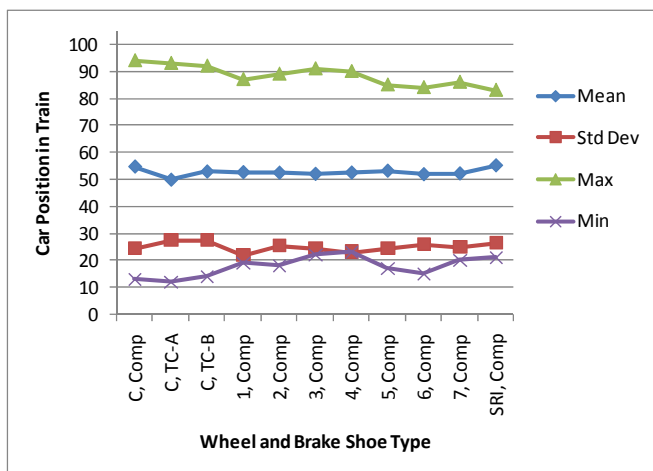


Figure 1. Each Combination of Wheel and Brake Shoe was Distributed throughout the Revenue Service Test Train

**PRETEST DATA COLLECTION**

Immediately after the rebuild, the UP routed the cars to TTC to allow for train assembly and initial data measurements. Profiles of each wheel in the train were recorded using Miniprof™ in order to accurately estimate wear rates of the wheels after they are removed from the train. Serial numbers of each wheel were also recorded to aid in identifying wheelsets after their removal.

Wheel/rail forces produced by cars in the test train were recorded and evaluated to ensure that cars with poor curving performance would not unduly influence the wheel life results of any particular wheel and brake shoe combination. The Wheel/Rail Mechanism Loop at TTC contains strain-gaged rail in 4-, 7.5-, and 10-degree curves. The train was operated on this loop in the clockwise and counterclockwise directions both before and after turning the train so that every wheel completed laps in the leading and trailing positions of a truck and on the inner and outer rails of the loop. Locomotive

engineers operated the train at three different speeds: 12, 24, and 32 mph. These speeds correspond to -2.5-, -1.5, and 0-inches cant deficiency in the 4-degree curve, -2.25-, 0, and 2.25-inches cant deficiency in the 7.5-degree curve, and -3-, 0, and 3-inches cant deficiency in the 10-degree curve.

Research by the Wheel Defect Prevention Research Consortium has shown that most rolling contact fatigue damage occurs on the leading wheelset of trucks in loaded cars on the low rail wheel while negotiating curves.<sup>6,7,8</sup> The cars were empty following the rebuild, and it was not practical for TTCI to load the cars. Rather, the data recorded from empty cars passing by the strain-gaged rails was used to evaluate the curving performance. Figure 2 shows the average value of the ratio of the lateral and vertical forces (L/V) produced by the wheels on the low rail in the leading position of each truck for each combination of wheel type and brake shoe type. The various wheel and brake shoe combinations are ranked in order of the overall average value and listed in descending order (i.e., cars equipped with the SRI wheels exhibited the worst overall curving performance, cars equipped with AAR Class C wheels, and TC-B brake shoes exhibited the best overall curving performance). This of course is due to truck condition unrelated to wheel chemistry.

According to shakedown theory,<sup>9</sup> fatigue damage on the wheel tread would be expected at L/V ratios of approximately 0.6 or greater for empty cars. Thus, the cars in the revenue service test train exhibit acceptable curving performance and the differences between cars equipped with different wheel and brake shoe types should not dominate the test results. This will be verified and regularly monitored using data from truck performance detectors once the cars are loaded and operating in revenue service.

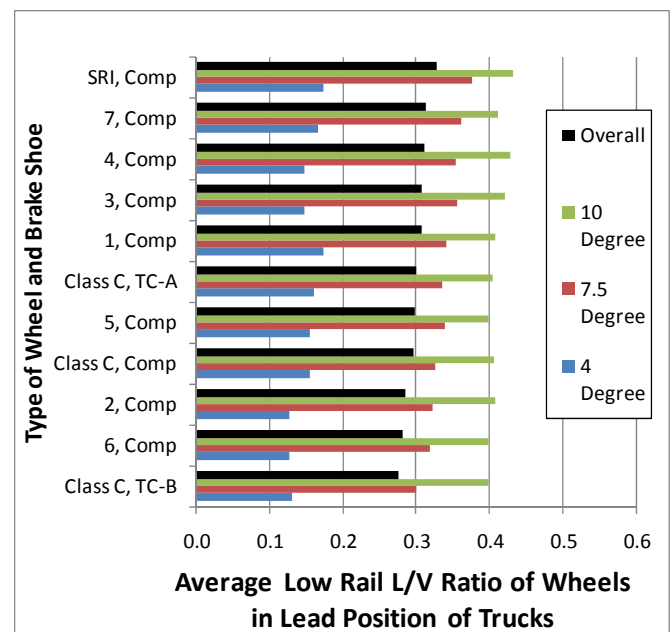


Figure 2. Average L/V Ratios

## REVENUE SERVICE TEST AND EVALUATION

The intended test duration is approximately three years to allow sufficient time for a statistically significant number of wheelset removals. The test train will not stay in captive service on a single point-to-point route during the test. Instead, the test train will typically be loaded with coal from one of the mines in Wyoming's Powder River Basin and transport the coal one of the power plants served by the UP. A typical round trip will include both an empty and a loaded pass through North Platte, Nebraska. A majority of the coal car wheelset change outs performed by the UP occurs in North Platte and this will be the intended site of wheelset change outs for the test train. At this facility, workers change out the wheelsets without removing the car from the train. This should minimize switching and aid in maintaining the test consist.

Data from wayside detectors will be used to monitor performance of the wheels and cars in the test train. Data analysis is planned for the following detector types:

- Wheel Impact Load Detector
- Wheel Profile
- Wheel Temperature
- Wheel Crack
- Truck Performance Detector

When wheelsets are removed from the train in accordance with AAR Interchange Rules, the wheelsets will be stored in a common location for inspection by personnel from TTCI, railroads, and wheel manufacturers. It is intended to inspect every wheelset removed from the train, regardless of the official reason for removal. Wheelset inspections will consist of the following:

- Wheel profile measurement
- Visual inspection of the tread surface for shells, spalls, fatigue cracks, and signs of heating (bluing)
- Application of an etching solution to the tread surface to identify the presence of any martensite.

Reliability engineering methods will be used to compare the different wheel and brake shoe combinations. Weibull analysis allows for a comparison between lifecycle data from two or more products. The characteristic life from the Weibull distribution ("scale parameter" — the projected time at which 63.2 percent of the components have failed) of the different wheel types will be compared. Wheels that were removed from shelling (no martensite in the vicinity of the largest shells) will be considered as failures; this could include Why Made Codes other than 75 "Tread Shelled." All other wheels will be considered successes. Weibull analysis allows for "censored data" to be used — wheels which are still in service at the time of the analysis are considered successes with a suspended test duration. Likewise, wheels that are removed from service for reasons other than shelling can also be used in the analysis. They will be considered successes with test duration equal to the length of time they were in service.

Although the shelling failures will be the main criteria for assessment, it may be important to note other trends with a particular type of wheel. Wear rates will be compared with Analysis of Variance methods.

## CONCLUSION

A revenue service test was initiated August 21 to quantify the benefits of eight types of high performance wheels paired with composition brake shoes in comparison to AAR Class C wheels paired with composition brake shoes and two types of tread conditioning brake shoes.

## ACKNOWLEDGEMENTS

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## REFERENCES

1. Robles, F., S. Kalay, and S. Cummings. 2009. "Properties and Microstructure of High Performance Wheels." *Technology Digest* TD-09-001. AAR/TTCI, Pueblo, CO.
2. Robles, F., S. Kalay, and S. Cummings. 2009. "Analysis of Residual Stresses on High Performance Wheels." *Technology Digest* TD-09-004. AAR/TTCI, Pueblo, CO.
3. Cummings, S. 2009. "High Temperature Tensile Properties of High Performance Wheel Steels." *Technology Digest* TD-09-026. AAR/TTCI, Pueblo, CO.
4. Cummings, S. 2009. "Drag Brake and Durability Tests of High Performance Wheels." *Technology Digest* TD-09-005. AAR/TTCI, Pueblo, CO.
5. Cummings, S. 2009. "Durability Test of High Performance Wheels: 20,000-Mile Interim Results." *Technology Digest* TD-09-020. AAR/TTCI, Pueblo, CO.
6. Cummings, S. and D. Lauro. 2008. "Inspections of Tread Damaged Wheelsets." RTDF2008-74009, *Proceedings of 2008 Fall Conference of the ASME Rail Transportation Division*, Chicago, IL.
7. Cummings, S. 2008. "Prediction of Rolling Contact Fatigue Using Instrumented Wheelsets." RTDF2008-74013, *Proceedings of 2008 Fall Conference of the ASME Rail Transportation Division*, Chicago, IL.
8. Cummings, S. and P. Krupowicz. 2008. "The Effects Of Wheelset Position and Operating Environment On Rolling Contact Fatigue." RTDF2008-74014, *Proceedings of 2008 Fall Conference of the ASME Rail Transportation Division*, Chicago, IL.
9. Bower, A.F. and K.L. Johnson. 1991. "Plastic flow and shakedown of the rail surface in repeated wheel-rail contact." *Wear*, 144, pp 1-18.

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