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Wayside Wheel Temperature Detector Test

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Summary

Wayside detectors are increasingly being deployed by railroads to identify poorly performing brake systems on cars and to identify reasons for this performance. This digest describes a test conducted by Transportation Technology Center, Inc. as part of the Association of American Railroads' Strategic Research Initiatives Program to give wayside wheel temperature detector (WTD) users a better understanding of the readings reported by these devices with respect to the effects of operating conditions and the relationship between WTD readings and wheel tread temperature. Determining the relationship between thermocouple tread measurements and WTD measurements will allow WTD users to gain additional utility from WTD measurements beyond simply identifying and diagnosing brake problems. It will allow WTD users to establish brake thermal performance limits to minimize thermal mechanical wheel shelling.

Findings from the test are as follows:

- WTD readings are sufficiently accurate for their primary purpose; i.e., to identify and diagnose brake problems.
- Train speed, direction of travel, and location of a wheelset within a car and truck had minimal influence on reported WTD values.
- Intense heating of short duration showed larger discrepancies between WTD readings and thermocouple readings than quasi-steady state conditions.
- WTD readings can be used to establish brake thermal performance limits to minimize thermal mechanical wheel shelling with understanding of the following:
  - In comparison to temperatures measured on the wheel tread with thermocouples, wheel temperatures reported by the WTD were approximately 100°F cooler when using the manufacturer's peak point filter algorithm and approximately 150°F cooler when using the manufacturer's averaging filter algorithm.
  - In some instances, the wheel flange became much hotter than the wheel rim and plate. In this case, the WTD reported temperatures as much as 500°F cooler than the thermocouples.

Different test procedures were used to explore the relationship between temperatures measured with the WTD and temperatures measured with contacting thermocouples, with variations in train speed, train direction, wheel temperature, and wheelset position within a car and truck. Data was collected during 29 passes of the WTD over the course of three test days.

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INTRODUCTION AND BACKGROUND

Wayside detectors are increasingly being deployed by railroads to identify poorly performing brake systems on cars and to identify reasons for this performance. The test described in this digest was conducted to give WTD users a better understanding of the readings reported by these devices. The effects of operating conditions were explored (train speed, direction, relative location of wheelset within a car) and the relationship between WTD readings and wheel tread temperature was quantified.

The wheel temperatures reported by WTD can be used to diagnose a variety of brake related problems with cars and trains. A relative indication of wheel temperature is sufficient to identify abnormally hot or cold wheels (and thereby detect and diagnose brake problems) and take action accordingly. However, the relationship between a temperature reported by a WTD and a temperature from another source, such as a thermocouple used in a laboratory dynamometer test, is not straightforward.

Most commercially available WTDs rely on a noncontacting thermal scan of the wheel rim and plate to determine the temperature of passing wheels. Pyrometers or bolometers are installed next to the track and usually aimed perpendicular to the rails, generally scanning passing wheels a few inches above the top of rail, as Figure 1 shows. In this way, WTDs measure the temperature of the wheel rim and plate, but not the hottest part of the wheel; i.e., the tread surface. This is quite different than the contacting thermocouples typically used to measure wheel tread temperature during dynamometer tests.

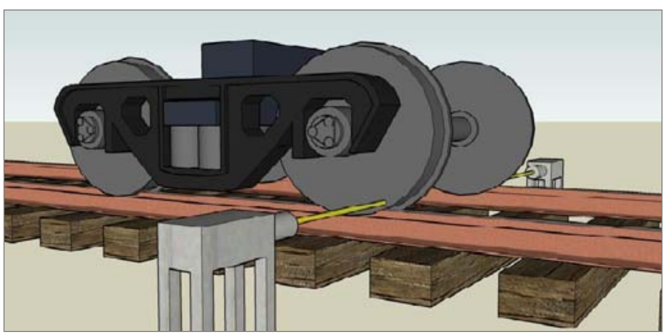

Figure 1. Schematic View of WTD Scan

Extensive laboratory dynamometer tests have been conducted in the past regarding the relationships between braking horsepower, wheel temperature, and wheel residual stress.[1] Determining the relationship between thermocouple tread measurements and WTD measurements will allow WTD users to gain additional utility from WTD measurements beyond simply identifying and diagnosing brake problems. It will allow WTD users to establish brake thermal performance limits to minimize thermal mechanical wheel shelling.

TEST SETUP

Tests were conducted at the Transportation Technology Center on the Transit Test Track, a 9.1-mile loop with no curves tighter than 1.5 degrees. The WTD was installed in a tangent zone, approximately 3,500 feet from the nearest curve. A representative of the detector's manufacturer oversaw the installation of the WTD. The WTD used a sample rate high enough to obtain multiple temperature readings of each wheel as it rolled past the inspection system. Ideally, this allows the WTD to obtain temperatures of a portion of the wheel plate and the rim just before and after it contacts the rail. The WTD manufacturer provides a peak point filter algorithm and an averaging filter algorithm which can be applied to the readings from each wheel. Both the peak point and average WTD temperature reading per wheel were used in the data analysis.

The test consist included a locomotive, an instrumentation coach, and a hopper car ballasted to a gross rail load of 286,700 pounds. The hopper car has truck-mounted brakes configured in a special arrangement on the B-end so that the brake cylinder pressure was controlled directly from a pressurized airline running through the instrumentation coach. This allowed the test crew to apply and release the brakes on the "test truck" independently of the rest of the train.

Both wheels of one "test wheelset" (position 1) in the test truck each had four contacting thermocouples: three across the tread surface and one on the rim face, as Figure 2 shows. The thermocouples were located approximately 180 degrees of wheel rotation from the brake shoe and anchored to the bearing adapter to minimize relative lateral motion with the wheel. Additional onboard measurements included brake cylinder pressure, brake beam force from an instrumented pin, train speed, and coupler force from an instrumented coupler installed in the trailing end of the locomotive.

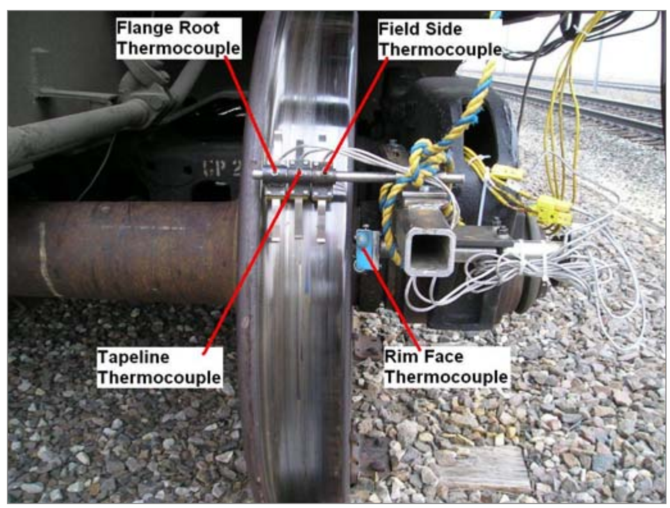

Figure 2. Thermocouple Arrangement

TEST PROCEDURE

Several testing procedures were used to explore the relationship between WTD temperature and thermocouple temperature, with variations in train speed, train direction, wheel temperature, and wheelset position within a car and truck. Data was collected during a total of 29 passes of the WTD over the course of three test days.

During days 1 and 3, the focus was to heat the wheels during the first two laps and then alternate full laps with reverse and forward moves past the WTD to maximize the amount of data collected in a single day. Test speeds were 30 or 40 mph and brake cylinder pressure was varied between 0 and 65 psi (full service). Testing on day 2 also began with two full laps with brakes applied on the test truck to heat the wheels. Additional testing on day 2 consisted of forward moves past the WTD at speeds ranging from 10 mph to 60 mph and brake cylinder pressure held constant at 40 psi. Reverse moves were not recorded on day 2. On test days 1 and 2 the test wheelset was in the leading position of the leading truck of the hopper. The test car was turned prior to day 3 so that the test wheelset was in the trailing position of the trailing truck. Table 1 lists important details of each day's testing.

Table 1. Test Details

Test Day	Ambient Temp. (F)	Number of WTD Passes	Train Speed (mph)	Brake Cylinder Pressure (psi)	Axle Position of Test Wheelset (Forward Moves)
1	50	11	30, 40	0, 20, 40, 65	Lead position of lead truck
2	65	8	10, 20, 30, 40, 50, 60	40	Lead position of lead truck
3	30	10	30, 40	20, 40, 65	Trail position of trail truck

TEST RESULTS

Because the tests were conducted on a loop track, the wheels of the test wheelset are labeled outer and inner to correspond with the outer rail of the loop and the inner rail of the loop, respectively. Figure 3 shows temperatures from the WTD and thermocouples in the order in which they were recorded on test days 1-3. Due to the extreme operating environment, not every thermocouple produced an accurate reading on every pass of the WTD. Results are only reported for thermocouple readings with a high level of confidence.

After reviewing the data, some anomalous conditions were observed. During the 40-psi brake cylinder testing on day 3, the flange root thermocouple of the inner wheel reported much hotter temperatures than the other thermocouples on the same wheel, and all of the thermocouples on this wheel reported much hotter temperatures than the WTD. This is thought to be due to the brake shoe pressing laterally against the wheel flange. Another anomaly occurred during day 3 when brake shoe wear caused the piston to run out of travel during the full lap with the brake cylinder pressure set to 65 psi. This resulted in lower than expected brake shoe forces and cooler temperatures. The brakes were released and reset prior to the ensuing reverse movement to allow the slack adjuster to remedy the situation.

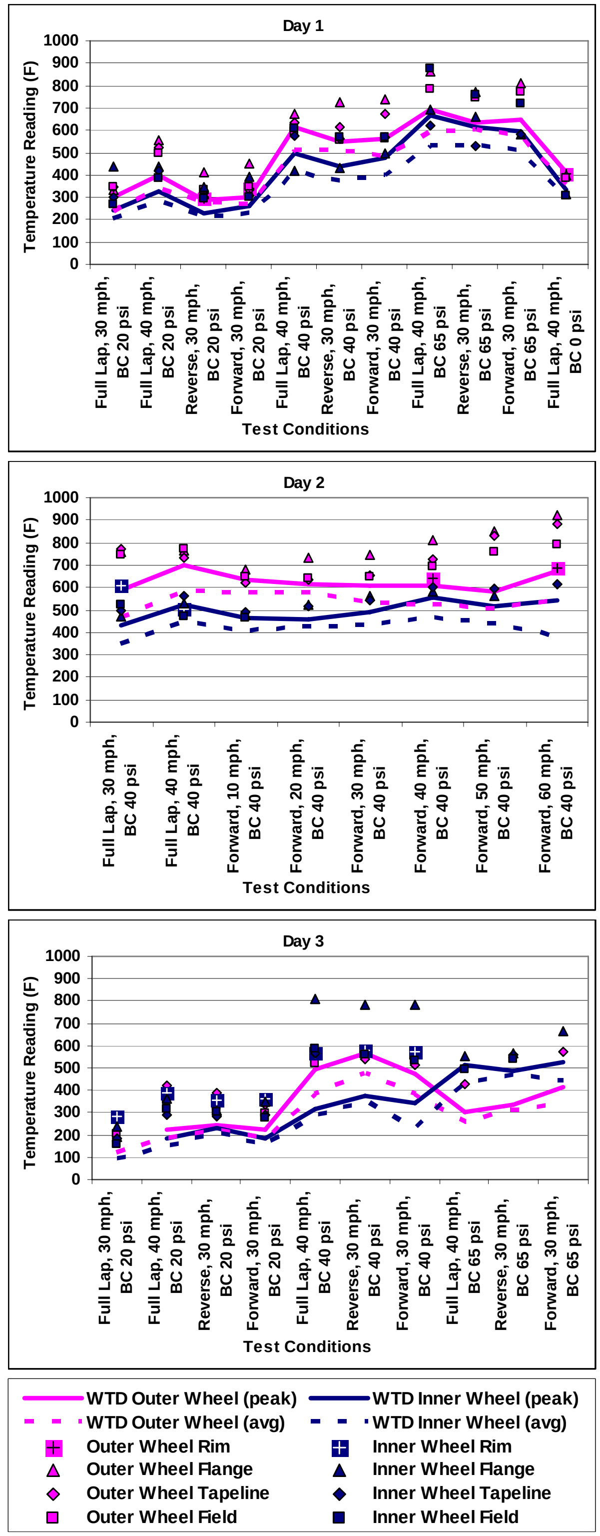

Figure 3. Testing Results Grouped by Test Day

Figure 4 shows the WTD peak point temperatures as a function of the thermocouple temperatures. The diagonal line represents perfect agreement between WTD and thermocouple. Most values are below the diagonal line, indicating that the temperatures reported by the WTD are lower than the temperatures reported by the thermocouples. The discrepancy increases as the thermocouple temperatures exceed about 800°F. This is likely due to the fact that wheel tread temperatures of this magnitude were not maintained for extended periods of time during the testing, and the heat transfer to the wheel plate is a time dependent process. This discrepancy is relatively unimportant for the detection of brake problems. Figure 5 shows the WTD average temperatures as a function of thermocouple temperatures. The trends are the same as in Figure 4, but the discrepancy between the WTD readings and the thermocouple readings is greater.

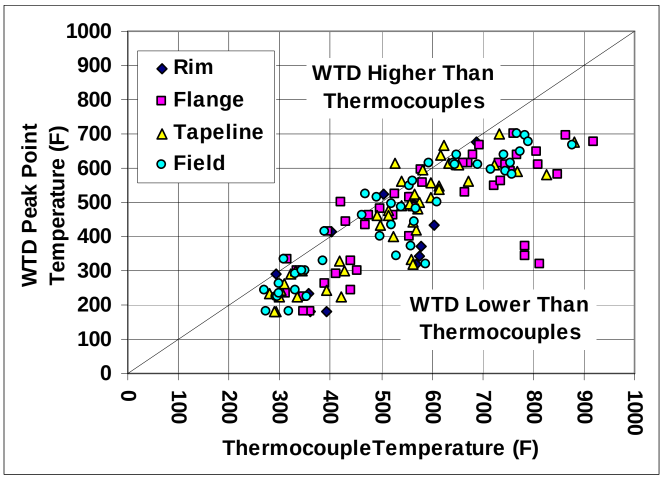

Figure 4. Thermocouple Temp. vs. WTD Peak Point Temp.

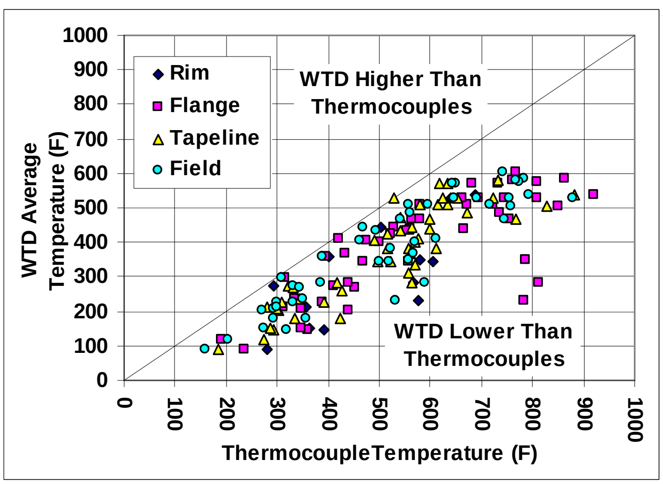

Figure 5. Thermocouple Temp. vs. WTD Average Temp.

Table 2 lists a statistical comparison between the WTD readings and the thermocouple readings. The difference (delta) between the WTD temperature and the thermocouple temperature was calculated individually for each case with a simultaneous reading. Negative delta values indicate that the WTD readings were cooler than the thermocouple readings. On average, the peak point WTD readings were between 82 and 122°F cooler than the thermocouple readings, and the average WTD readings were between 139 and 179°F cooler than the thermocouple readings.

Table 2. Comparison of WTD and Thermocouple Readings

	Comparison of Thermocouples to WTD Peak Point Reading				Comparison of Thermocouples to WTD Average Reading			
	Rim	Field Side	Tapeline	Flange Root	Rim	Field Side	Tapeline	Flange Root
WTD Temp. Range	181 - 702				91 - 603			
Thermocouple Temp. Range	158 – 920							
Number of Samples	14	47	48	48	14	47	48	48
Mean Delta	-122	-82	-86	-121	-169	-139	-146	-179
Median Delta	-149	-82	-69	-119	-168	-117	-134	-158
Maximum Delta	22	58	84	79	-19	-12	2	-12
Minimum Delta	-280	-269	-274	-493	-345	-348	-342	-554
Std Dev Delta	109	71	78	117	99	81	74	117

CONCLUSION

- WTD readings are sufficiently accurate for their primary purpose; i.e., to identify and diagnose brake problems.
- Train speed, direction of travel, and location of a wheelset within a car and truck had minimal influence on reported WTD values.
- Intense heating of short duration showed larger discrepancies between WTD readings and thermocouple readings than quasi-steady state conditions.
- WTD readings can be used to establish brake thermal performance limits to minimize thermal mechanical wheel shelling with understanding of the following:
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REFERENCE

1. Stone, D.H. and G.F. Carpenter. 1994. "Wheel Thermal Damage Limits." *Rail Transportation*, RTD – Volume 7, ASME (New York, 1994) pp. 57-63.