U.S. Department of Transportation

Federal Railroad Administration

Using Wheel Temperature Detector Technology to Monitor Railcar Brake System Effectiveness

Office of Research and Development
Washington, DC 20590

DOT/FRA/ORD-13/50

Final Report
December 2013

REPORT DOCUMENTATION PAGE			*Form Approved OMB No. 0704-0188*
Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.			
1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE December 2013		3. REPORT TYPE AND DATES COVERED Technical Report
4. TITLE AND SUBTITLE Using Wheel Temperature Detector Technology to Monitor Railcar Brake System Effectiveness			5. FUNDING NUMBERS DTFR53-00-C-00012 Task Order 252
6. AUTHOR(S) Jim Robeda, Devin Sammon, and Benjamin Madrill			
7. PERFORMING ORGANIZATION Transportation Technology Center, Inc. P. O. Box 11130 Pueblo, CO 81001			8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) U.S. Department of Transportation Federal Railroad Administration Office of Research and Development Washington, DC 20590			10. SPONSORING/MONITORING AGENCY REPORT NUMBER DOT/FRA/ORD-13/50
11. SUPPLEMENTARY NOTES COTR: Monique Stewart			
12a. DISTRIBUTION/AVAILABILITY STATEMENT This document is available to the public through the FRA Web site at http://www.fra.dot.gov.			12b. DISTRIBUTION CODE
13. ABSTRACT (Maximum 200 words) Wheel temperature detector technology has been used extensively in the railroad industry for the past several decades. The technology has traditionally been used to identify wheels with elevated temperatures. There is currently a movement in the industry to detect railcars with ineffective brakes by using the technology to identify wheels that have lower than expected temperatures when a train is in a braking mode or condition. This report documents a study to determine the effectiveness of the technology in distinguishing between applied and nonapplied brakes when a train passes a wheel temperature detector with train brakes applied. The study used controlled testing as well as data from revenue service operations to investigate the effectiveness of the technology and to compare its capabilities with the current manual inspection process.			
14. SUBJECT TERMS Wheel temperature detector, ineffective brake, air cut out, bad order, cold wheel			15. NUMBER OF PAGES 32
			16. PRICE CODE
17. SECURITY CLASSIFICATION OF REPORT Unclassified	18. SECURITY CLASSIFICATION OF THIS PAGE Unclassified	19. SECURITY CLASSIFICATION OF ABSTRACT Unclassified	20. LIMITATION OF ABSTRACT

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. 239-18
298-102

METRIC/ENGLISH CONVERSION FACTORS

ENGLISH TO METRIC

LENGTH (APPROXIMATE)

1 inch (in)	=	2.5 centimeters (cm)
1 foot (ft)	=	30 centimeters (cm)
1 yard (yd)	=	0.9 meter (m)
1 mile (mi)	=	1.6 kilometers (km)

AREA (APPROXIMATE)

1 square inch (sq in, in^2)	=	6.5 square centimeters (cm^2)
1 square foot (sq ft, ft^2)	=	0.09 square meter (m^2)
1 square yard (sq yd, yd^2)	=	0.8 square meter (m^2)
1 square mile (sq mi, mi^2)	=	2.6 square kilometers (km^2)
1 acre = 0.4 hectare (he)	=	4,000 square meters (m^2)

MASS - WEIGHT (APPROXIMATE)

1 ounce (oz)	=	28 grams (gm)
1 pound (lb)	=	0.45 kilogram (kg)
1 short ton = 2,000 pounds (lb)	=	0.9 tonne (t)

VOLUME (APPROXIMATE)

1 teaspoon (tsp)	=	5 milliliters (ml)
1 tablespoon (tbsp)	=	15 milliliters (ml)
1 fluid ounce (fl oz)	=	30 milliliters (ml)
1 cup (c)	=	0.24 liter (l)
1 pint (pt)	=	0.47 liter (l)
1 quart (qt)	=	0.96 liter (l)
1 gallon (gal)	=	3.8 liters (l)
1 cubic foot (cu ft, ft^3)	=	0.03 cubic meter (m^3)
1 cubic yard (cu yd, yd^3)	=	0.76 cubic meter (m^3)

TEMPERATURE (EXACT)

[(x-32)(5/9)] [= y ☐C

METRIC TO ENGLISH

LENGTH (APPROXIMATE)

1 millimeter (mm)	=	0.04 inch (in)
1 centimeter (cm)	=	0.4 inch (in)
1 meter (m)	=	3.3 feet (ft)
1 meter (m)	=	1.1 yards (yd)
1 kilometer (km)	=	0.6 mile (mi)

AREA (APPROXIMATE)

1 square centimeter (cm^2)	=	0.16 square inch (sq in, in^2)
1 square meter (m^2)	=	1.2 square yards (sq yd, yd^2)
1 square kilometer (km^2)	=	0.4 square mile (sq mi, mi^2)
10,000 square meters (m^2)	=	1 hectare (ha) = 2.5 acres

MASS - WEIGHT (APPROXIMATE)

1 gram (gm)	=	0.036 ounce (oz)
1 kilogram (kg)	=	2.2 pounds (lb)
1 tonne (t)	=	1,000 kilograms (kg)
	=	1.1 short tons

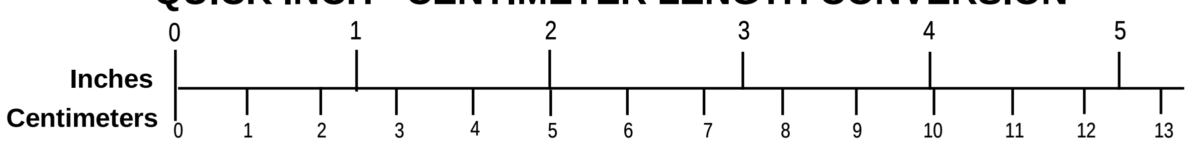
VOLUME (APPROXIMATE)

1 milliliter (ml)	=	0.03 fluid ounce (fl oz)
1 liter (l)	=	2.1 pints (pt)
1 liter (l)	=	1.06 quarts (qt)
1 liter (l)	=	0.26 gallon (gal)
1 cubic meter (m^3)	=	36 cubic feet (cu ft, ft^3)
1 cubic meter (m^3)	=	1.3 cubic yards (cu yd, yd^3)

TEMPERATURE (EXACT)

[(9/5) y + 32] | = x ☐F

QUICK INCH - CENTIMETER LENGTH CONVERSION



QUICK FAHRENHEIT - CELSIUS TEMPERATURE CONVERSIO

°F	-40°	-22°	-4°	14°	32°	50°	68°	86°	104°	122°	140°	158°	176°	194°	212°
°C	-40°	-30°	-20°	-10°	0°	10°	20°	30°	40°	50°	60°	70°	80°	90°	100°

For more exact and or other conversion factors, see NIST Miscellaneous Publication 286, Units of Weights and Measures. Price $2.50 SD Catalog No. C13 10286

Updated 6/17/98

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Executive Summary

The primary objective of this research project was to demonstrate the capability of wheel temperature detector technology to evaluate brake effectiveness by comparing relative wheel temperatures within a train. A properly working brake system is defined by its ability to produce at least the minimum designed amount of force to slow the train while maintaining piston travel distance to less than the proposed maximum for that car.

Proof-of-concept testing demonstrated the ability of wheel temperature detectors to distinguish between applied and nonapplied brakes for known braking conditions. This implies that it is also possible to make this distinction for unknown braking conditions when sound statistical methods are applied.

In an attempt to more closely replicate revenue service conditions, testing was conducted over several days with a fully loaded test train operating at track speeds at the Facility for Accelerated Service Testing (FAST) of the Transportation Technology Center (TTC). This testing allowed the consist wheels to reach a steady-state temperature prior to brake application. Data collected during this controlled fully loaded train testing were independently analyzed by two engineers using different methodologies. The cars identified as having ineffective brakes were the same in both cases. This implies that there may be multiple ways to analyze the data to produce reliable results.

The controlled testing helps validate the revenue service detector results that show a brake-related defect detection rate of approximately four times that of the manual inspection defect detection rate. Revenue service detector results that show several cars with a repeated “cold-wheel” condition over the course of multiple trips past the detector indicate a failure of the manual test to properly identify “ineffective” brakes. The failure of the manual test to identify these ineffective brakes may be due to the fact that the manual test only verifies brake application and has no way of measuring brake effectiveness. Additionally, the manual test is conducted under static conditions that do not account for possible vibration-induced control valve failures during dynamic operation. Finally, the manual test requires that the brake remain applied for only three minutes. In revenue service, train brakes are often applied and must hold for much longer periods.

Testing to examine the correlation between piston travel and applied shoe force shows that force can vary for constant piston travel when the brake rigging configuration is altered. This variation can be attributed to the action of the automatic slack adjuster common to modern railcars. The slack adjuster maintains constant piston travel as brake rigging changes occur. Brake rigging changes, such as lever angularity and brake rod lengths, while not affecting piston travel (because of the action of the automatic slack adjuster), have a definite effect on shoe force. Therefore, proper piston travel does not ensure adequate shoe force.

1. Introduction

The *Code of Federal Regulations*, Title 49 Part 232.103, requires that every car in a departing train have an effective brake. CFR 49 Part 232.5 gives the following definition of effective and properly functioning brakes:

> *Effective* means a brake that is capable of producing its nominally designed retarding force on the train. A car's air brake is not considered effective if it is not capable of producing its nominally designed retarding force or if its piston travel exceeds:
>
> (1) 10.5 inches for cars equipped with nominal 12-inch stroke brake cylinders; or
>
> (2) The piston travel limit indicated on the stencil, sticker, or badge plate for that brake cylinder.

Brake effectiveness is normally evaluated by railroads during the Class 1 (initial terminal) and subsequent Class 1A (1,000-mile) brake inspections. This routine inspection and evaluation is based on a visual check of the brake rigging and piston travel as prescribed above. Figure 1 shows an example of proper piston travel. In addition, the nominally designed retarding force has a hold-time component that is currently accounted for by the 3-minute allowance for a Class 1 or Class 1A retest. However, there is no measurement of brake force. By using wheel temperature detector technology to assess wheel temperatures as a train with applied brakes passes a sensor, Transportation Technology Center, Inc. (TTCI) submits that an indirect measurement of brake force can be made, thus providing a better indication of brake effectiveness that also accounts for true revenue service hold-time.

Figure 1. Braking Tank Car with Proper Piston Travel

1.1 Background

Wheel temperature detector technology has been used extensively by North American freight railroads for several decades to monitor the mechanical condition of passing trains. Railroad experience with the technology in revenue service applications has shown the capability to identify problems associated with wheels, bearings, and brake systems, along with giving railroad personnel timely notification before a potentially catastrophic failure occurs. TTCI conducted a test program to study the value of this technology for use in determining train brake system effectiveness. This project was jointly funded by the Federal Railroad Administration's (FRA), Office of Research and Development, Office of Railroad Policy and Development, and the Association of American Railroads' (AAR) Strategic Research Initiatives Program.

In traditional applications, wheel temperature detectors are generally set to alarm for elevated wheel temperatures above a predetermined threshold. Such elevated temperatures may result from defective brake rigging or brake control valves, applied hand brakes, or various other brake system defects. In recent years, railroads have begun looking for temperatures considerably lower than the average and using existing technology to monitor wheel temperatures on trains that have the brakes applied since low wheel temperature would give an indication of an inoperative or ineffective brake. When used for this purpose, the wheel temperature detectors are generally placed at a stationary, wayside location where train brakes would typically be applied, such as on a long, descending grade. Thus, using the technology to identify wheels in a train that are measurably colder than the expected temperature threshold as they pass the detector provides a method of detecting a possible brake system defect.

The hypothesis behind this study is that wheel temperature measurements on moving trains are an indirect measure of the applied brake system retarding force and that this methodology exceeds the ability of an inspector to manually objectively determine brake effectiveness using piston travel as the sole indicator.

It should be noted that individual wheel temperatures (for braking and nonbraking conditions) are affected by several variables such as rim thickness, amount of flange to rail contact, track lubrication, track curvature, truck condition, etc. This variation is generally normally distributed and can be normalized by using sound statistical methods. The idea is to look for obvious outliers when trying to determine brake effectiveness.

1.2 Objectives

The primary objective of this research project was to demonstrate the capability of wheel temperature detector technology in evaluating brake effectiveness by comparing relative wheel temperatures within a train. In addition, tests were conducted to investigate the correlation between piston travel and brake shoe force.

1.3 Overall Approach

The project attempted to meet its objectives by concentrating on the following five major tasks:

Task 1: Benchmarking wheel failure rates found with manual inspection practices

Task 2: Compiling data from wheel temperature detectors to determine failure rates through use of this technology

Task 3: Demonstrating the ability and effectiveness of the technology in distinguishing between applied and released brakes

Task 4: Investigating the correlation between piston travel and brake shoe force

Task 5: A direct comparison of the two methodologies

These tasks were accomplished through controlled testing as well as limited monitoring of revenue service train operations.

1.4 Scope

The scope of this project included benchmarking manual inspection results, as well as reviewing wheel temperature detector data results provided by a Class 1 railroad over a 1-year period. In addition, several controlled tests were conducted at TTC in Pueblo, CO, to evaluate and demonstrate the capabilities of the technology in effectively monitoring railcar brake systems and to investigate the correlation between piston travel and brake shoe force.

1.5 Organization of the Report

This report is organized into four major sections: Section 1—the project's background, objectives, overall approach, and scope; Section 2—the methodology used to accomplish the project objectives; Section 3—the results from each of the project tasks and applicable data; and Section 4—the results, conclusions, and recommendations.

2. Methodology

As part of a cooperative research effort between FRA and AAR, TTCI was tasked to investigate the feasibility of using wheel temperature detector technology to evaluate brake effectiveness.

2.1 Benchmarking Manual Inspection Results

Data on manual inspection results were collected by Union Pacific (UP) Railroad for two series of coal cars that are operated by UP from the Powder River Basin through North Platte, NE, to unloading facilities in Illinois, Arkansas, and Wisconsin. One series was relatively new with a history of very few problems. The second series was older with a history of more problems. Data were collected from October 2010 through September 2011. Figure 2 shows the UP route map highlighting loading, unloading, and inspection locations.

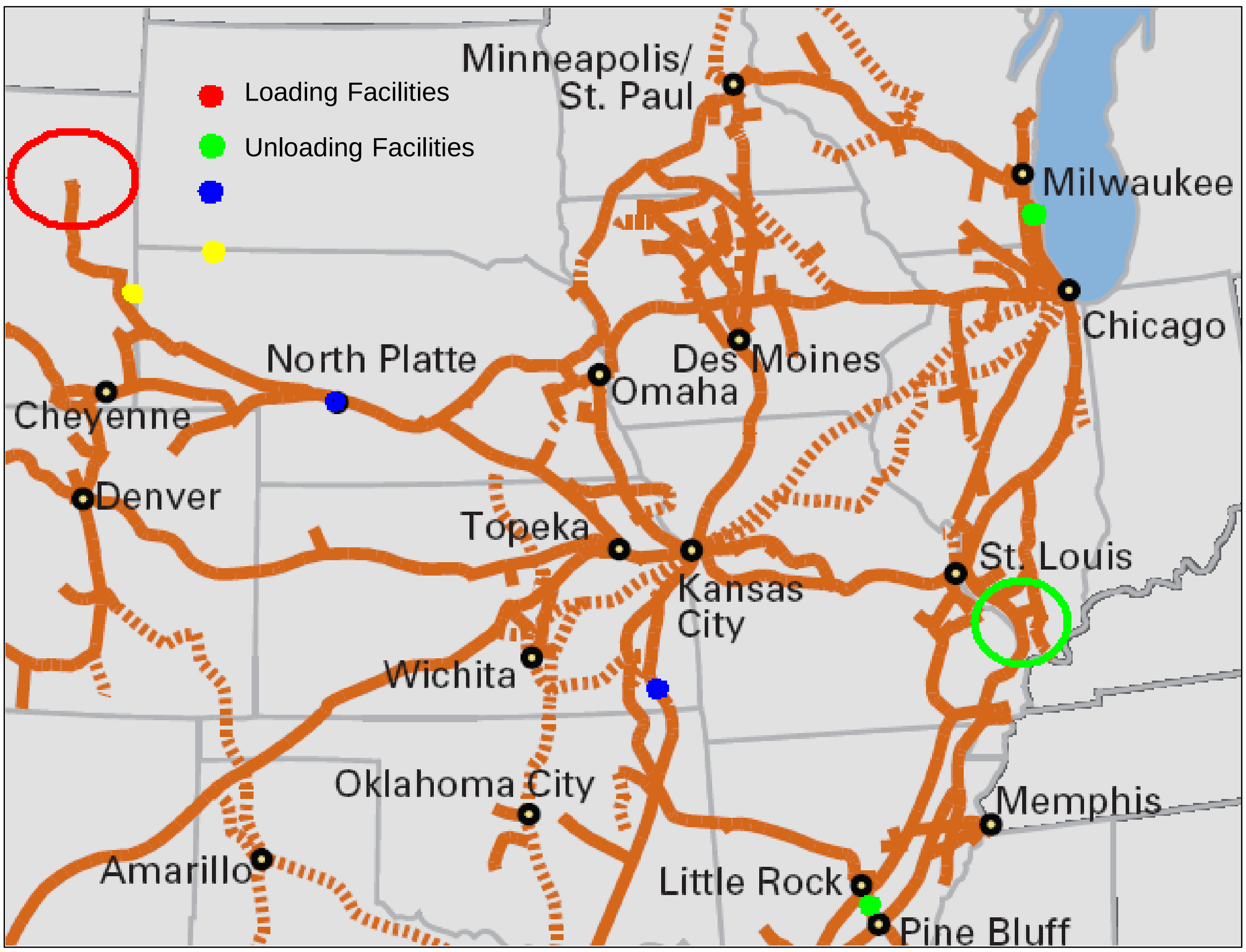

Figure 2. UP Route Map Highlighting Loading, Unloading, and Inspection Locations

2.3 Compiling Wheel Temperature Detector Data

UP also provided detector data results for the period October 2010 through September 2011. Wheel temperature detector data were collected for the same equipment sets that were monitored for manual inspection results. Only trains that passed the detector site were compared with manual inspection results.

The detector site that was used is located at Sheep Creek, WY (Powder River Subdivision, Milepost 198.20), which is approximately midway between North Platte, NE, and the loading facilities of the Powder River Basin. This section of track is a descending grade of slightly more than 1 percent. Braking trains make an average brake pipe reduction of 7 pounds per square inch (psi), and brakes are applied for an average of 4.9 minutes ahead of the detector.

Using a specialized filtering algorithm, UP uses the wheel detector data to calculate a "filtered temperature" from the running average of the train. Comparison of the raw data and the filtered data is made to classify the train into one of three categories: clearly braking, clearly nonbraking, or unclassified braking. Once a train is determined to be clearly braking, a normalized value for each wheel is calculated. This value is the ratio of the actual wheel temperature over the filtered temperature. A normalized value of less than 0.3 for any given truck indicates a cold-wheel condition that implies an ineffective brake that has a temperature (F) less than 30 percent of the running average.

UP provided the calculated results that show if a car had a cold- or hot-wheel condition. Figure 3 shows an example of the raw detector data with the filtered temperatures, as well as the normalized values for a sample train.

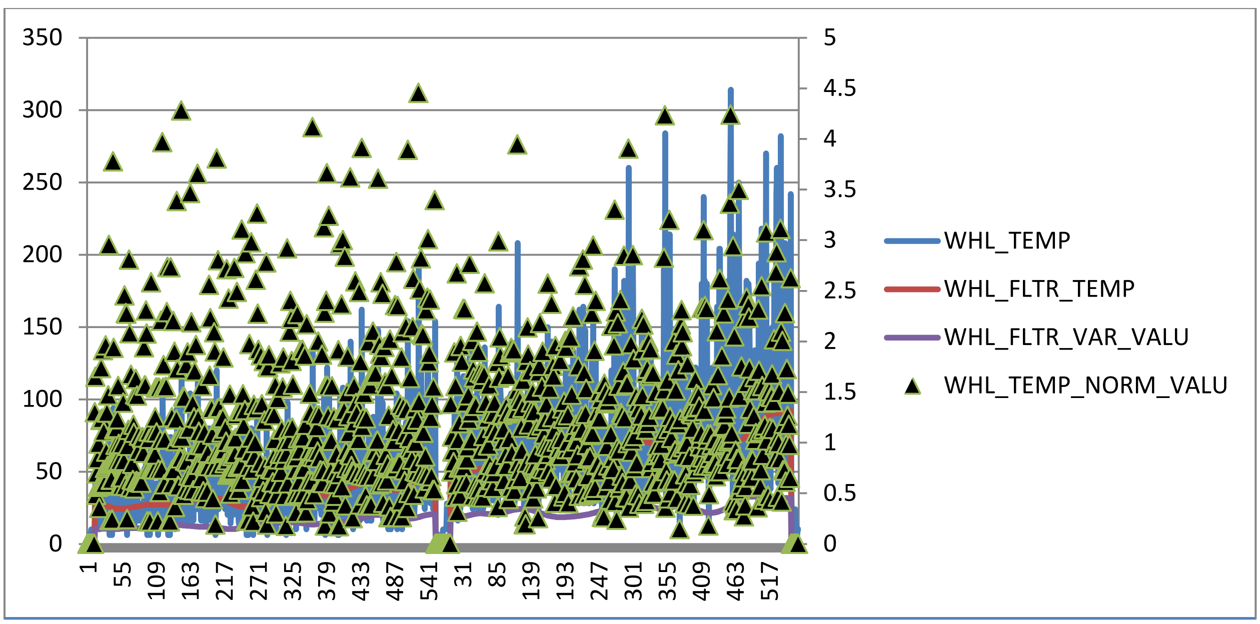

Figure 3. Wheel Temperature Detector Data Sample

2.5 Demonstrating the Effectiveness of the Technology

Several different demonstration tests were performed using the wheel temperature detector located on track at FAST. FAST is a 2.7-mile closed loop consisting of short tangent sections connecting 5- and 6-degree curves. The test train consist at FAST is made up of aluminum coal gondolas loaded to 315,000 pounds. These cars all have truck-mounted brake arrangements. Initial testing used a short train of one locomotive and 13 cars. This was primarily a proof-of-concept test to demonstrate the basic premise of using the technology to distinguish between known applied and released brakes. Subsequent testing used a train of approximately 105 aluminum coal gondolas and 4 locomotives. These tests were meant to more closely replicate revenue service conditions.

2.6 Investigating Piston Travel versus Force

The correlation between piston travel and brake shoe force was investigated using the JIM SHOE® Brand Brake Force Measurement System. Brake rigging configurations were manipulated to create conditions that could possibly affect piston travel and/or brake shoe force at the wheel tread interface (e.g., lever angularity, binding rigging, and/or malfunctioning slack adjuster).

2.7 Comparing Methodologies (manual inspection versus technology detection)

Data collected for task one (see Section 2.1) and task two (see Section 2.2) were used to compare the results of the current manual inspection process with wheel detector technology detection capabilities.

3. Results

3.1 Benchmarking Manual Inspection Results

Results of manual inspections from 49 of the newer equipment trains, as well as inspection results from 270 of the older equipment trains were provided by UP for a total of 319 trains.

All of the newer equipment trains underwent Class 1 initial terminal air brake testing performed by train crew personnel in accordance with CFR 49 Part 232.205 at either the loading or unloading facilities. Approximately half of these trains (51 percent) also underwent Class 1A, 1,000-mile air-brake testing performed by mechanical department personnel at North Platte, NE, in accordance with CFR 49 Part 232.207.

No defects were reported for any of the newer equipment trains at any location during the test period.

The majority of the older equipment trains also underwent Class 1 initial terminal air-brake testing performed by train crew personnel in accordance with CFR 49 Part 232.205 at either the loading or unloading facilities. Approximately two-thirds of these trains (67 percent) also underwent Class 1A, 1,000-mile air-brake testing performed by mechanical department personnel at North Platte, NE, or Parsons, KS, in accordance with CFR 49 Part 232.207.

Defects were reported for a total of 44 cars. Of these, 37 were reported at North Platte, NE, 5 were reported at Parsons, KS, 1 at Coffeyville, KS, and 1 at Lexington, NE. Only 18 of the 44 cars show car repair billing records for brake-related defects (see Table 1). Of these, 15 were repaired at North Platte, NE, 2 were repaired at Parsons, KS, and 1 was repaired at Coffeyville, KS.

Car repair billing records indicate that only two cars had repairs coded Test Repair or Valve Repair (see Table 1). The remaining repairs were coded as Shoe/Key or General Repair (see Table 1).

Brake repairs were generalized into four groups based on Job Codes listed in the *2011 Field Manual of the A.A.R. Interchange Rules*, as Table 1 shows.

Table 1. Brake Repair Categorization by Job Code
(*Field Manual of the A.A.R. Interchange Rules*)

Test Repair	Valve Repair	Shoe/Key Repair	General Repair						
1139	1277	1830	1116	1403	1452	1450	1212	1658	1592
1140	1279	1838	1268	1404	1454	1612	1216	1660	1594
1145	1281	1840	1270	1405	1456	1160	1220	1662	1596
1146	1283	1842	1272	1406	1476	1162	1224	1670	1598
1147	1285	1843	1276	1408	1480	1164	1227	1672	1600
1150	1287	1844	1303	1411	1484	1165	1228	1680	1601
1151	1289	1845	1313	1413	1488	1172	1232	1696	1768
1152	1291	1846	1316	1414	1490	1180	1236	1697	1770
1155	1293	1852	1318	1415	1496	1184	1244	1698	1792
1157	1296	1999 **	1320	1416	1498	1188	1260	1742	1794
1159	1298		1340	1417	1500	1192	1264	1556	1796
	1301		1356	1418	1502	1194	1492	1574	1800
	1304		1360	1419	1504	1196	1628	1576	1802
	1308		1386	1422	1505	1197	1629	1578	1804
	1311		1388	1424	1506	1198	1630	1580	1808
	1321		1392	1428	1516	1200	1650	1584	1812
	1323		1400	1440	1520	1204	1652	1586	1814
	1325		1401	1444	1524	1208	1654	1588	1816
	1999 *		1402	1448	1532	1210	1656	1590	1999 ***

* with qualifiers AC, AK
** with qualifiers BE, BF
*** with qualifiers AA-BV, CR-DX, EB-EG excluding BE, BF, AC, AK

3.2 Compiling Wheel Temperature Detector Data

Detector results were provided by UP for the 319 trains documented above. The results show only one cold-wheel and one hot-wheel indication by the detector located at Sheep Creek for the 49 newer equipment trains. Neither of these cars shows a car repair billing record. A total of 76 cold-wheel indications and 2 hot-wheel indications were reported by the detector at Sheep Creek for the 270 older equipment trains.

A total of 43 different cars accounted for the 76 cold-wheel indications. Of these, 27 had a single indication of cold wheels, 7 had two indications, 2 had three indications, 6 had four indications, and 1 had five indications. The two cars with hot-wheel indications were unique.

Car repair billing records show repairs on 10 of the 43 cars with cold-wheel indications. However, these repairs are coded as Shoe/Key or General Repair (see Table 1). There are no records of brake valve replacement or single-car air-brake tests for any of these cars.

3.3 Demonstrating the Effectiveness of the Technology

A wheel temperature wayside detector previously installed at FAST was used for this demonstration test. The wheel temperature detector was provided by the Inspection and Information Systems Division of Progress Rail Services. Figure 4 shows the wheel temperature detector in track at FAST.

Figure 4. Wheel Temperature Detector Installation at FAST

3.3.1 Proof-of-Concept Testing

The initial proof-of-concept testing was conducted for 2 days in November 2010. The test was conducted in two separate stages. For the first stage, a test train of 13 cars and 1 locomotive was used. The test train was composed of cars with effective brakes as well as select cars with disabled brakes. The test train made several laps without a brake application. A minimum brake application was then made, and a sufficient number of laps were run to raise the wheel temperatures on the braking cars to a level not to exceed 350 ˚F.

For the second stage, the approach was to operate the test train with a hand brake applied on one car. The test train made several laps past the detector with the brakes released. The temperature of the consist wheels was then monitored to determine the ability of the technology to detect stuck brakes.

Before the start of the test, a manual inspection of the train bakes was performed. This manual inspection was done in accordance with CFR Part 49 Section 232.207 Class 1A—1,000-mile Air Brake Test. The inspectors walked the length of the train with the brakes applied and noted the brake rigging condition, piston travel, and position and condition of the brake shoes. The brakes were then released, and the inspectors rewalked the test train to ensure that the brakes were effectively released. The manual inspection determined that the brake system was in compliance with CFR 49 Part 232.207.

Once the inspection was completed and before the start of the test, the brake system was cut out on the 4th and 13th cars of the consist. The test started with a low-speed safety track conditioning run (TCR) to determine whether the track was in suitable condition for higher speed runs. Once the track was deemed safe, the train made five laps under normal operating conditions at 40 mph. On the sixth lap, a 10-pound per square inch brake-pipe reduction was made to apply the brakes, and the train maintained the 40-mile per hour speed while continuing laps. The wheel temperature was monitored with each pass. After three laps at 40 mph with brakes set, wheel temperature detector data indicated that the wheels had reached the predetermined safe temperature limit. The brakes were released, and the first day of the test was concluded. The test train was stored overnight so that the wheels in the consist could cool for the second day of testing. Figure 5 shows the results from the first day of testing.

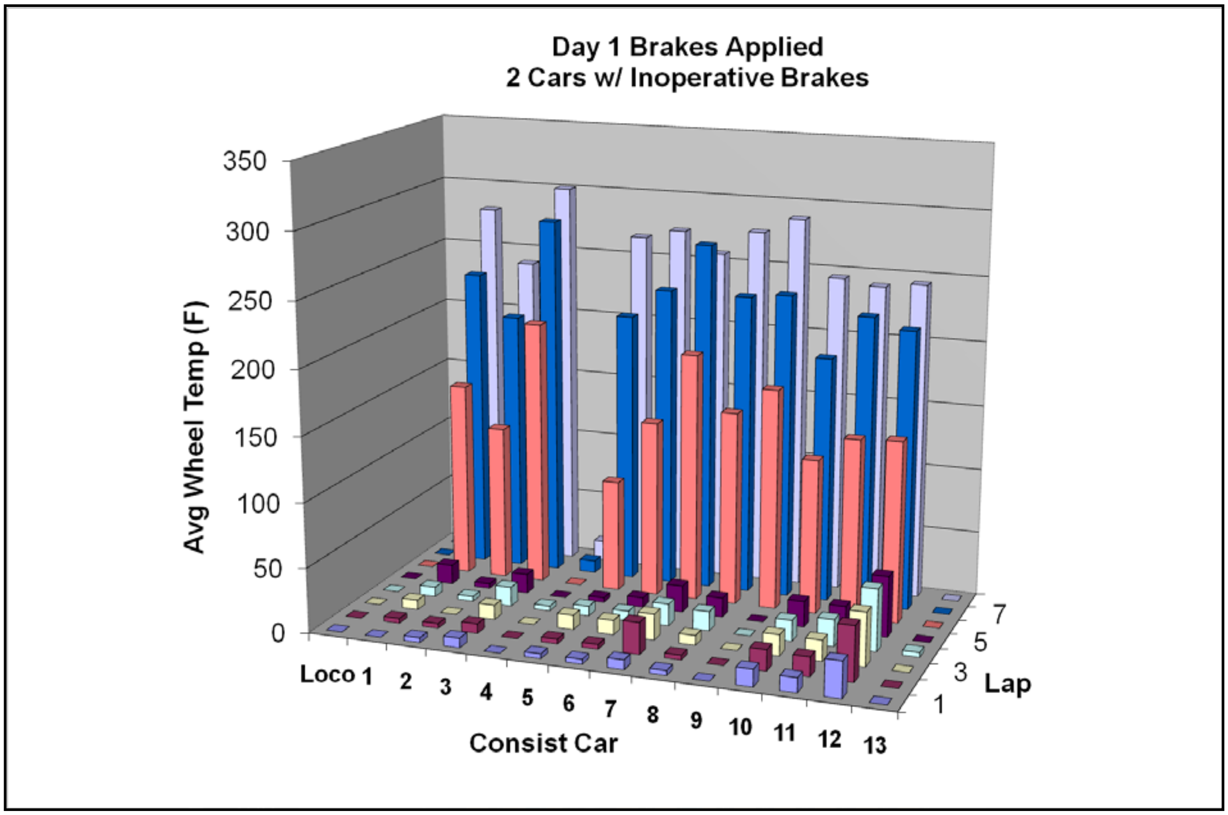

Figure 5. Proof-of-Concept Test Data—Day 1 Results

The data shows an increase in wheel temperatures once a brake application was made and for each subsequent lap for the cars with known operating brakes. Little or no wheel temperature increase is seen for the cars with known inoperative brakes.

For the second day of the test, all of the brakes were cut in and operative. Before testing began, a hand brake was set on the fifth car of the test train. The train was then taken through a TCR and operated at 40 mph for several laps past the wheel temperature detector. Wheel temperatures were closely monitored. When wheel temperatures on the sixth car reached the predetermined safe temperature limit, the train was stopped, and the hand brake was released. The train was started again and completed two more laps past the detector. Figure 6 shows the results from the second day of testing.

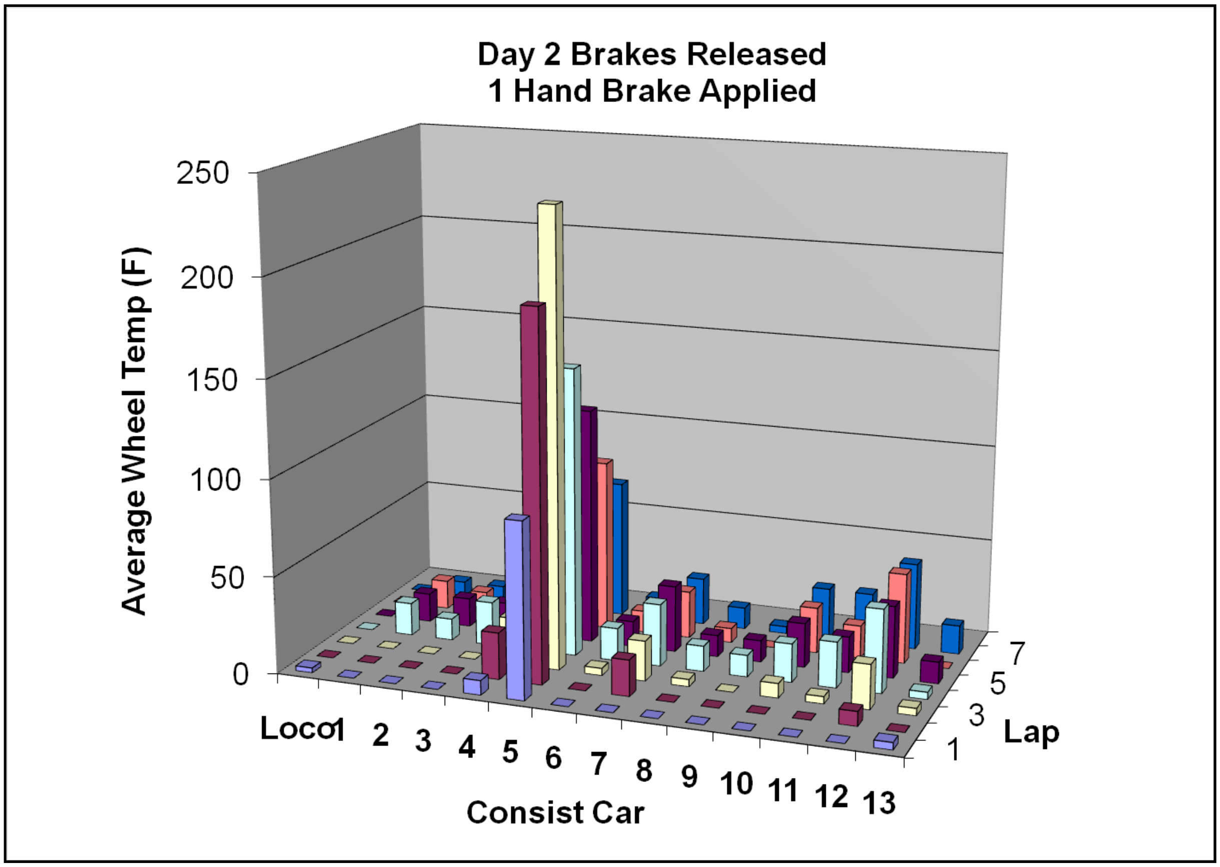

Figure 6. Proof-of-Concept Test Data—Day 2 Results

The data shows increasing wheel temperatures for the car with the applied hand brake on each subsequent lap until the hand brake is released. Wheel temperatures decrease on this car on each subsequent lap once the hand brake is released. Wheel temperatures for the remaining cars in the consist increase somewhat during the course of the test. These results prompted the idea to conduct a test that would let the wheels reach a steady-state operating temperature before making a brake application.

3.3.2 Controlled Fully Loaded Test Train Operating at Track Speeds

In an attempt to more closely replicate revenue service conditions, testing was conducted over several days with a fully loaded test train operating at track speeds. This testing allowed the consist wheels to reach a steady-state temperature prior to a brake application. Previous proof-of-concept testing did not do this, and the temperature differential between braking and nonbraking wheels may have been more pronounced. This testing was conducted in October and November 2011. The testing took place on three different days over a 3-week period.

Normal operations at FAST were conducted during the test period with the exception of periodic brake applications to generate wheel temperature detector data for the braking condition over the course of testing. The test train varied from 102 to 106 cars with 4 locomotives during the 3 tests running under normal operational conditions. A brake-pipe reduction of 6 psi was used for the brake applications on 2 of the test days, and a 10-pound per square inch reduction was used on the final day of testing.

Once a steady-state wheel temperature was reached, a brake application was made and held for two laps past the detector (approximately 5 miles), and then the brakes were released. This was done twice on the first and second day of testing. Only one brake application was made on the final day of testing because of operational problems not associated with the test. After the first day of testing, one car in the test train (FAST car number 286, shown as the control car on the graphs) had the air brakes cut out so that data for that car could be used to compare operating and nonoperating brakes under known conditions.

To determine the steady-state nonbraking condition, wheel temperature detector data was used to compute an average wheel temperature for the entire train, as well as an average wheel temperature for each car prior to the brake application. Once the brakes were applied, data from the second pass by the detector was used to compute train and car averages for the braking condition.

The average wheel temperature for each car was compared with the train average. A lower limit was established at two average deviations below the train average. Temperatures that fell below the lower limit were considered a cold-wheel condition, indicating a car with an ineffective brake. Figures 7 through 10 show the results of the train runs from the first day of testing.

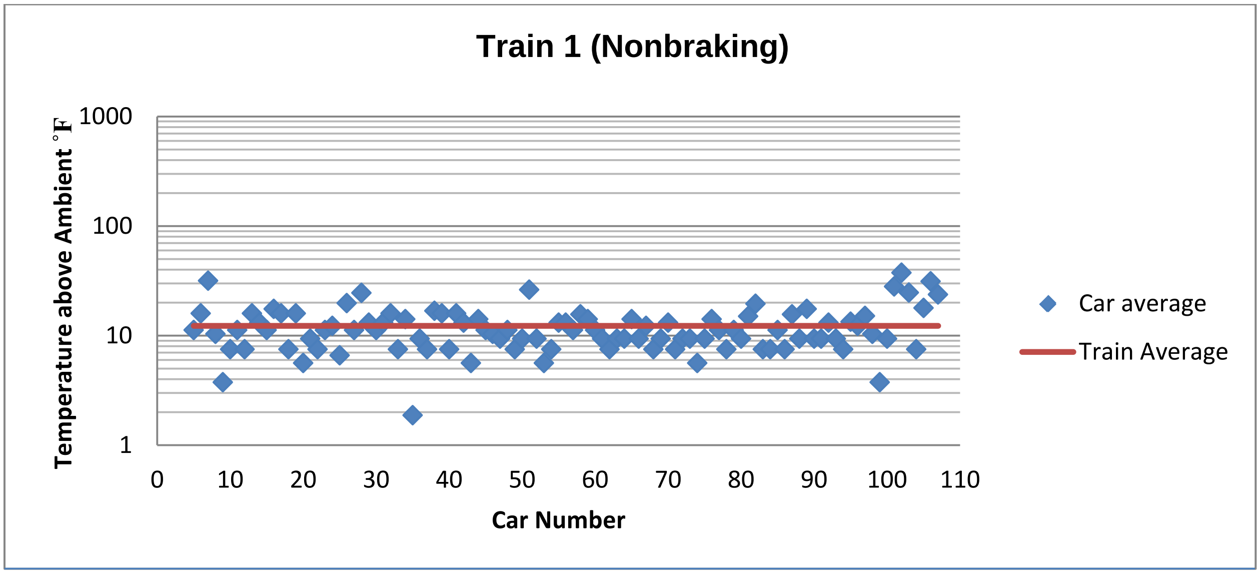

Figure 7. Loaded Test Train 1—Day 1 Results

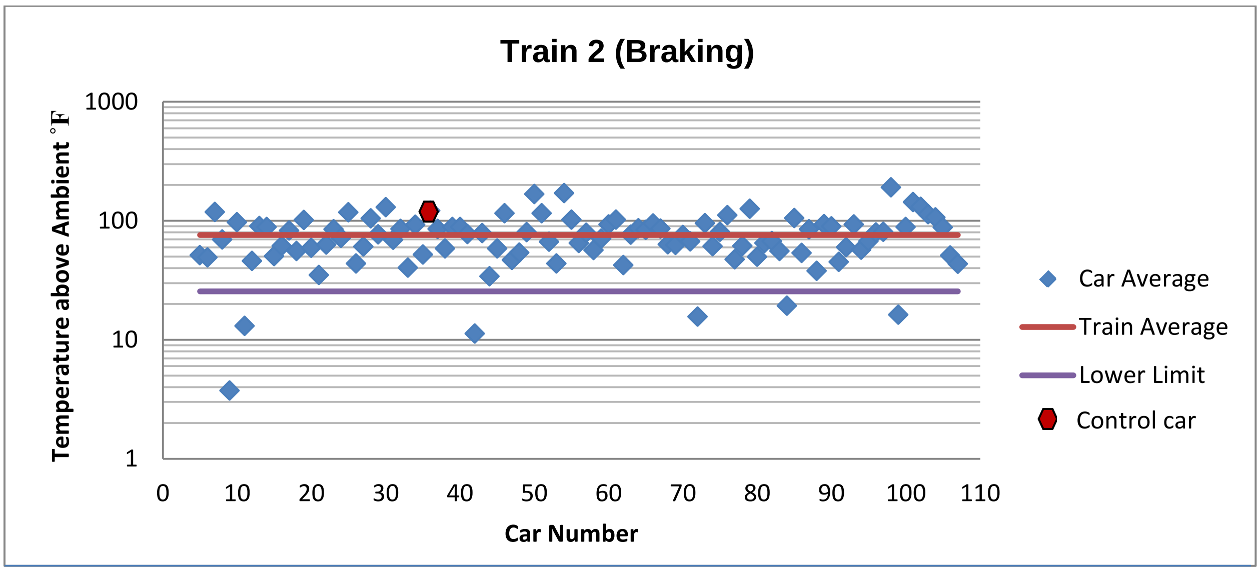

Figure 8. Loaded Test Train 2—Day 1 Results

Data for Train 2 shows that six cars fall below the lower limit threshold indicating possible ineffective brake conditions.

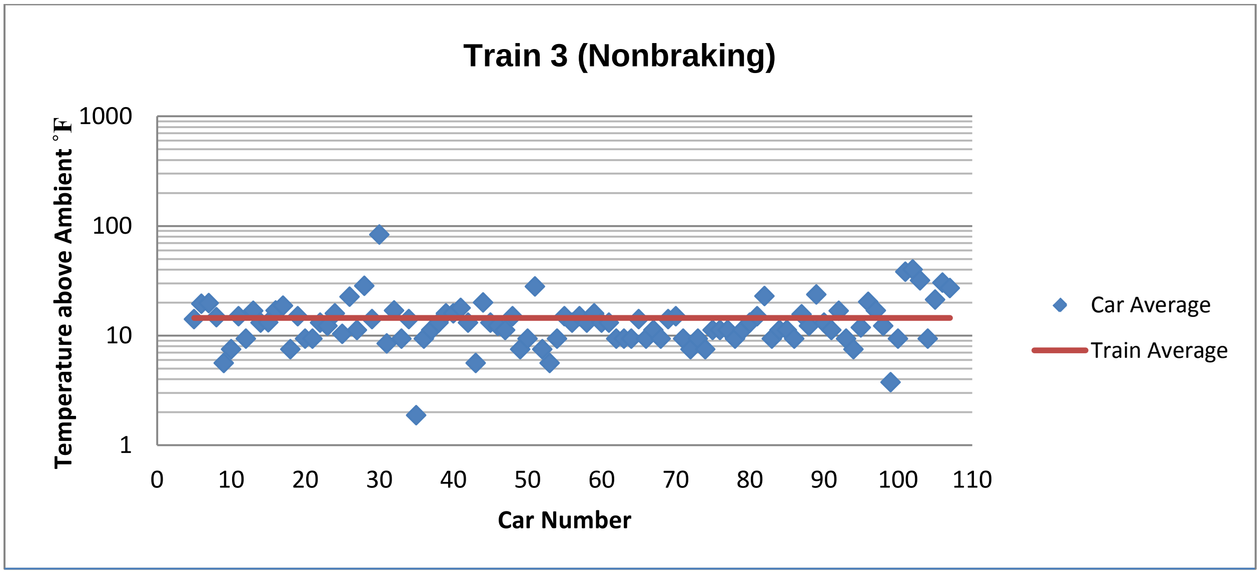

Figure 9. Loaded Test Train 3—Day 1 Results

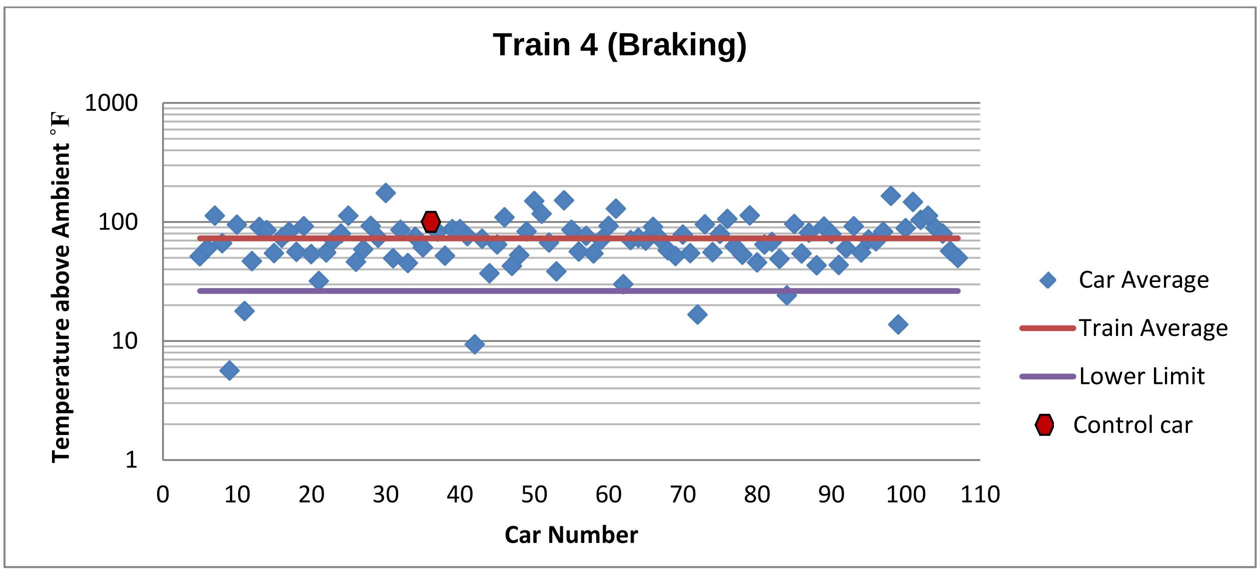

Figure 10. Loaded Test Train 4—Day 1 Results

The data for Train 4 show that the same six cars that fell below the lower limit threshold during the first brake application were again below the threshold.

The test was repeated with some changes to the train due to normal operational conditions. On the second day of testing, one car in the consist (FAST car number 286, shown as the control car on the graphs) had its brake system cut out to facilitate comparison of a car with a known ineffective brake with the train average. Figures 11 through 14 show the results from the second day of testing.

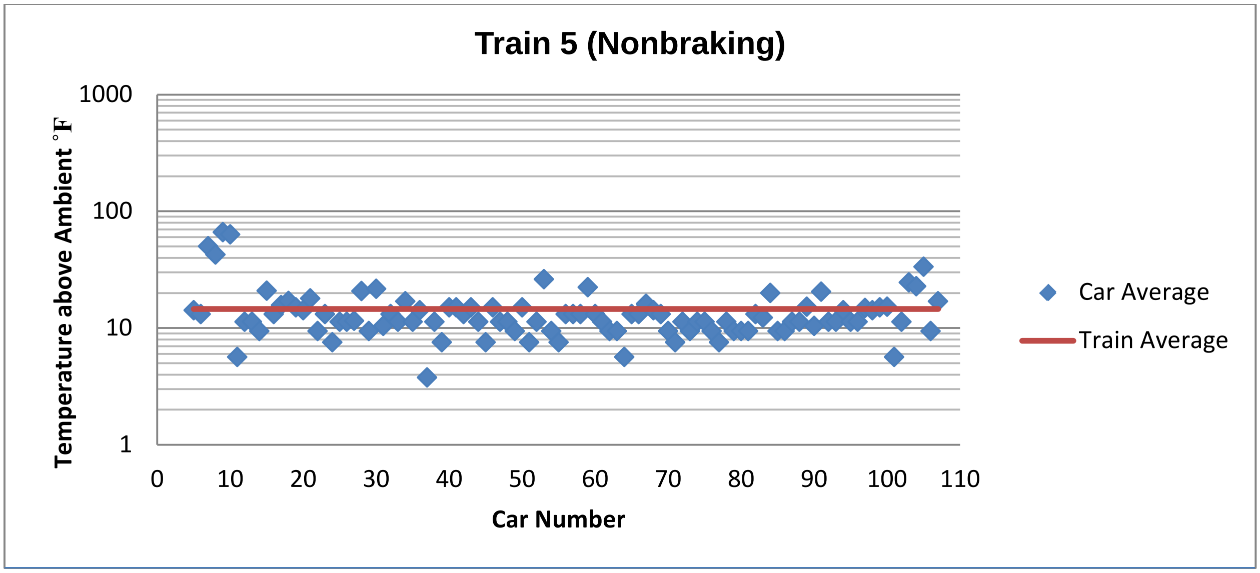

Figure 11. Loaded Test Train 5—Day 2 Results

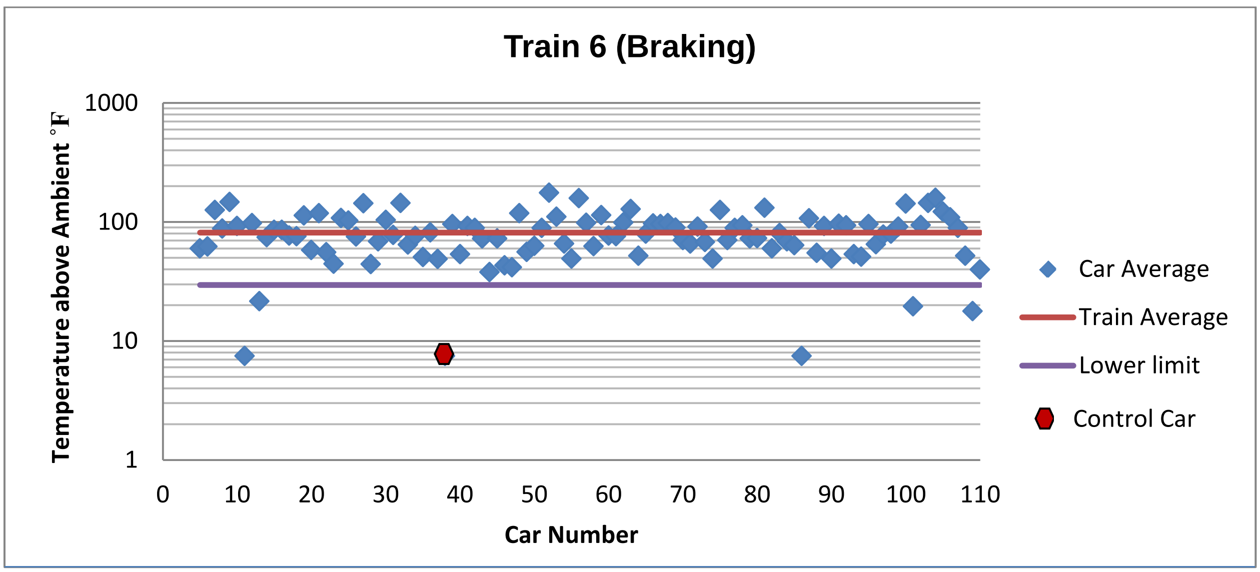

Figure 12. Loaded Test Train 6—Day 2 Results

Data for Train 6 again shows that six cars fall below the lower limit threshold, indicating possible ineffective brake conditions. Four of these six cars also showed an ineffective brake condition on both trains in the previous tests. Of the remaining two cars, one is the car that was purposely cut out for the test, and one is a car that was not in the test train during the previous test. The two additional cars that fell below the threshold in the previous tests were still in the consist but did not fall below the threshold during this test.

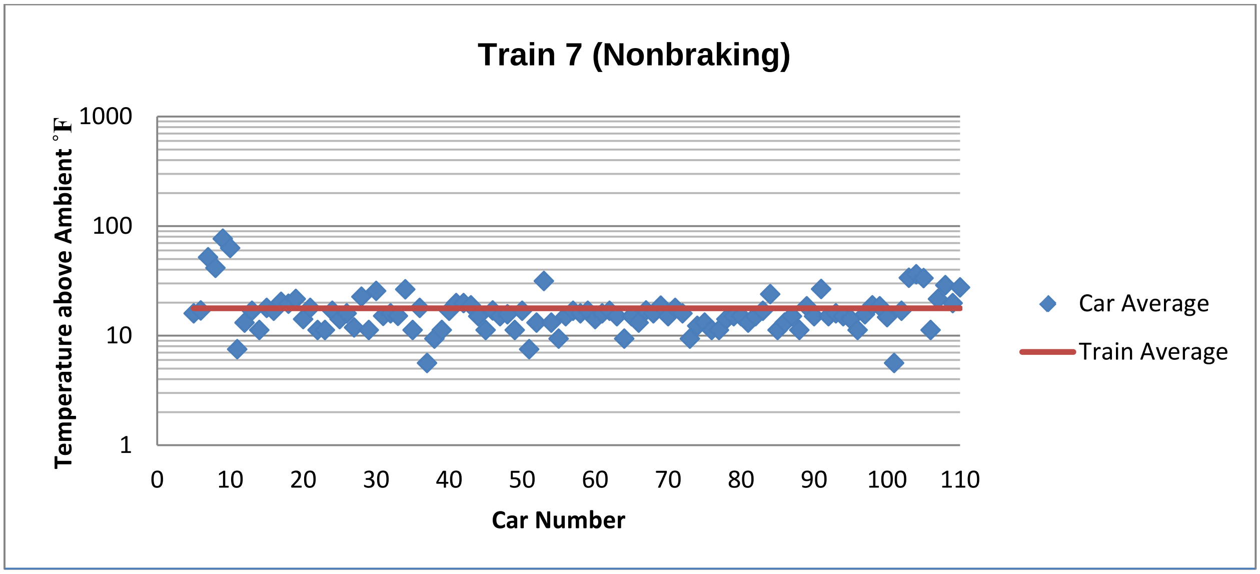

Figure 13. Loaded Test Train 7—Day 2 Results

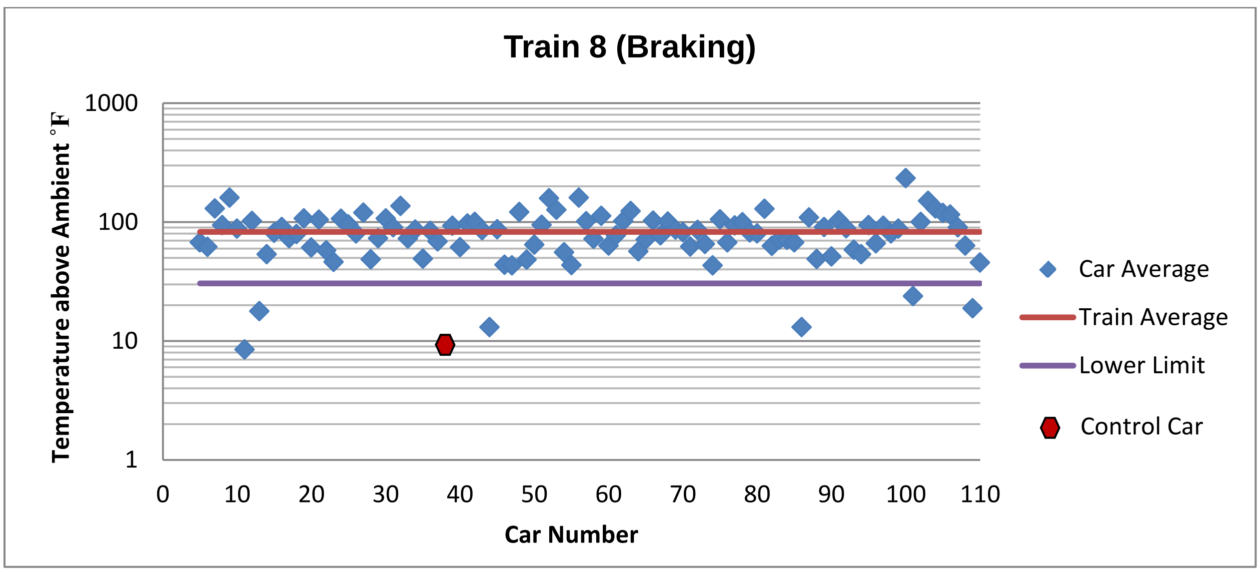

Figure 14. Loaded Test Train 8—Day 2 Results

The data for Train 8 shows seven cars below the threshold. The same six cars that fell below the lower limit threshold during the first brake application were again below the threshold. One additional car also fell below the threshold during this brake application. This is one of the two cars that fell below the threshold during the first day of testing that were subsequently above the threshold during the first brake application.

For the final day of testing, the train position was again slightly changed because of normal operational considerations. The car that had been cut out for the previous test was left in the consist, and the air was still cut out. A brake pipe reduction of 10 psi was used to make the brake application on the final day of testing. Figure 15 and Figure 16 show the results from the third and final day of testing.

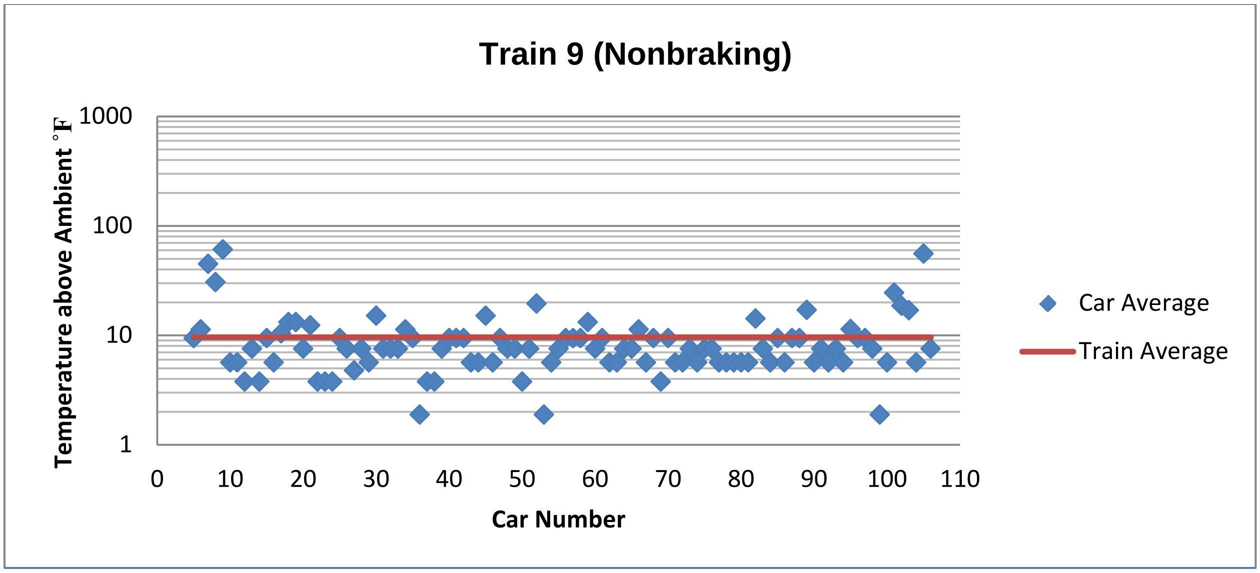

Figure 15. Loaded Test Train 9—Day 3 Results

Data for Train 10 shows seven cars that fall below the threshold. These are the same seven cars that were below the threshold for Train 8 during the second day of testing.

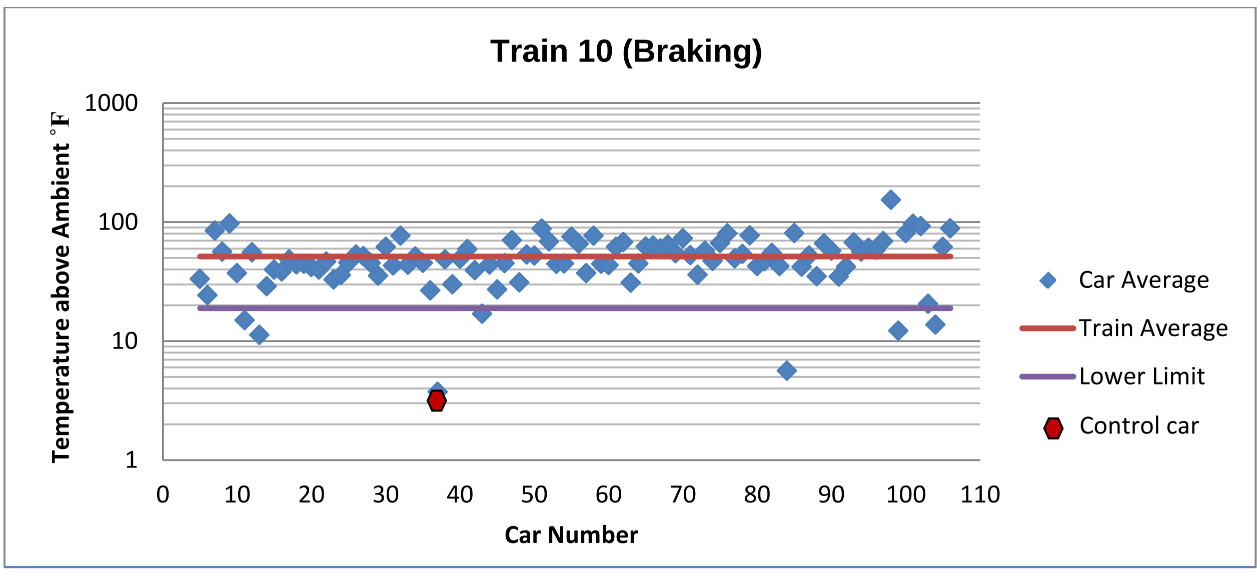

Figure 16. Loaded Test Train 10—Day 3 Results

3.4 Investigating Piston Travel versus Force

Current manual brake inspections use piston travel as an indicator of brake effectiveness. Several tests were conducted to determine the relationship between piston travel and brake shoe force. Two cars, one with body-mounted brakes and one with truck-mounted brakes, were tested. The JIM SHOE® Brand Brake Force Measurement System was used during these tests.

Force measurements were taken and recorded for the car with body-mounted brakes in the nominal condition, with a brake lever disconnected and a bound brake beam. Several 20-pound per square inch brake pipe reductions were used to allow the automatic slack adjuster to adjust piston travel to 7 inches. Figure 17 shows the results.

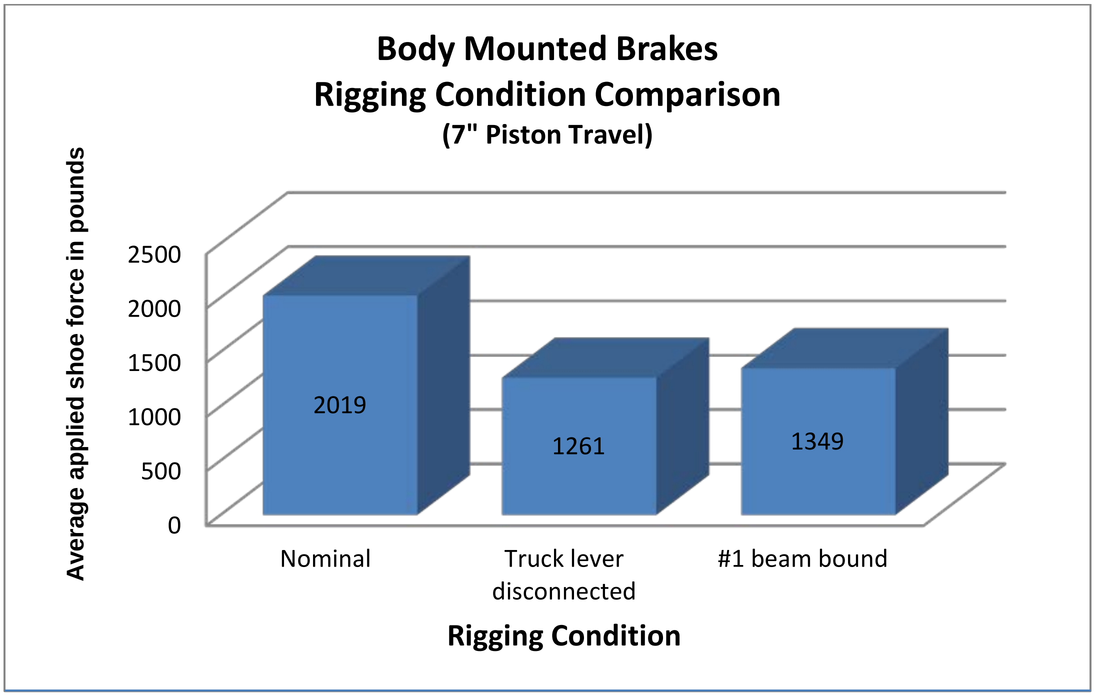

Figure 17. Body-Mounted Brakes—Rigging Condition Comparison (7-inch piston travel with 20-psi brake pipe reduction)

Applied shoe force is reduced by approximately 39 percent for the manipulated rigging conditions with constant piston travel of 7 inches.

Force measurements were taken and recorded for the car with truck-mounted brakes in the nominal condition and with a bound brake beam. The piston travel indicator was within range for both of the brake applications. Figure 18 shows the results.

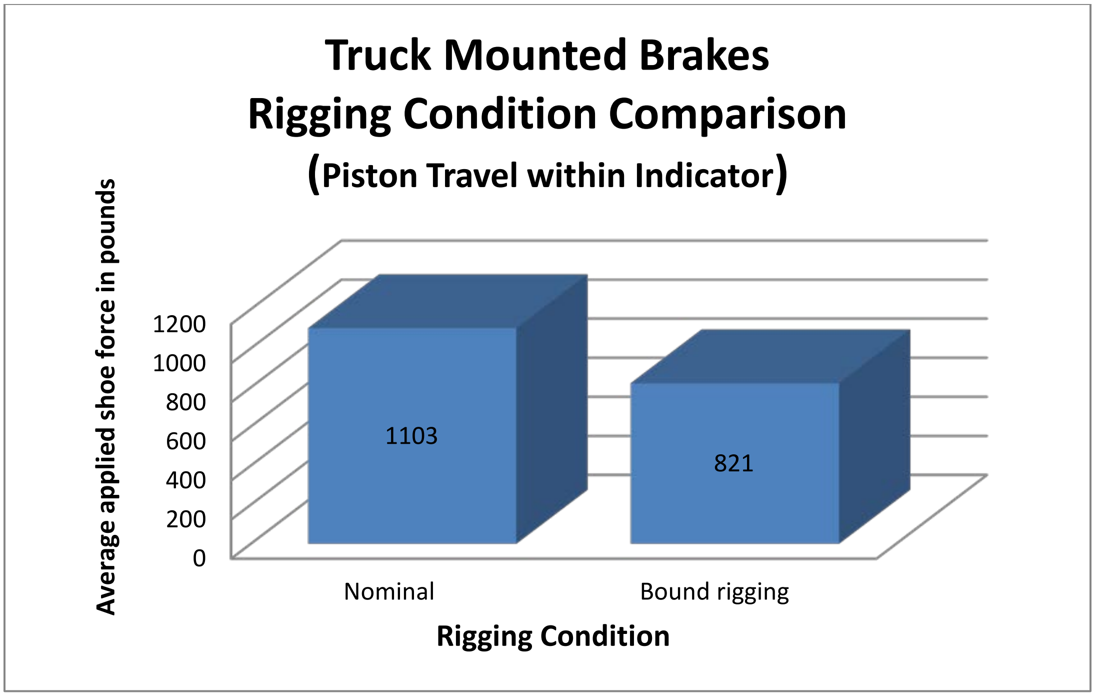

Figure 18. Truck-Mounted Brakes—Rigging Condition Comparison (nominal piston travel with 20-psi brake pipe reduction)

Bound rigging reduced brake shoe force by approximately 25 percent, whereas the piston travel indicator stayed within the acceptable range.

3.5 Comparing Methodologies (manual inspection versus technology detection)

Results of the revenue service manual inspection benchmarking study show that brake-related defects were found at the rate of 0.06 defects per train.

Revenue service wheel temperature detector results show that possible brake-related defects were found at the rate of 0.24 defects per train.

One car that was identified with a cold-wheel condition by the detector on May 26, 2011, was subsequently found defective at North Platte, NE, during a manual inspection on June 1, 2011. Car repair billing records indicate that the car was repaired at North Platte on June 3, 2011, and the repair was coded General Repair (see Table 1). There were no more defect indications for this car by either manual inspection methods or the detector.

None of the air-brake defects found by the manual inspections were identified as possible defects by the technology. Therefore, the true defect rate may lie somewhere between 0.06 and 0.24 defects per train.

The technology identified seven cars with possible ineffective brakes during controlled fully loaded train testing at FAST. After the test was completed, qualified inspectors performed a Class 1A 1,000-mile air-brake test. Five cars did not meet the Class 1A inspection criteria. Only one car was found defective by both the detector and the manual inspection. It should also be noted that one of the cars that failed the manual test was not in the consist during controlled fully loaded train testing. Manual and controlled fully loaded train test results for these 11 cars are shown in Table 2.

Table 2. Manual and Controlled Full Train Test Results for Defective Cars

FAST Car No.	Manual Test (Class 1A)	WTD Test	Temperature above or below(-) lower control limit (F°) (WTD Test)					Remarks
			Train 2	Train 4	Train 6	Train 8	Train 10	
260	Fail	Pass	50.5	52.2	62.1	55.5	54.5	
317	Fail	Pass	90.2	90.8	81.1	96.2	50.0	
269	Fail	Pass	19.7	17.2	24.3	28.1	16.0	
272	Fail	N/A	N/A	N/A	N/A	N/A	N/A	Not in consist for WTD test
117	Fail	Fail	-9.9	-9.7	19.6	12.7	17.2	Failed WTD test 1st night only
360	Pass	Fail	-14.3	-17.0	8.4	-17.4	-1.9	
367	Pass	Fail	-12.4	-8.5	-7.9	-12.7	-7.6	
395	Pass	Fail	-21.8	-20.7	-22.1	-22.0	-3.9	
249	Pass	Fail	-6.2	-2.2	-22.1	-17.4	-13.3	
217	Pass	Fail	-9.3	-12.6	-9.9	-6.7	-6.6	
143	Pass	Fail	N/A	N/A	-11.7	-11.7	-5.1	Not in consist 1st night WTD test
286	Control	Control	96.0	74.4	-22.1	-21.2	-15.1	Air cut out after 1st night WTD test

The control car (FAST car number 286) had the air cut out after the first night of testing. The defective cars were each given a manual single-car air-brake test. Table 3 shows the test results.

Table 3. Results of Single-Car Air-Brake Test

				Defects						
FAST Car No.	Manual Test (Class 1A)	WTD Test	Single Car Air-Brake Test	Pressure Tap Gasket Leaking	Train Line Leaking	Auxiliary Reservoir Pipe Broken	Cylinder Pipe Leaking	Cylinder Packing Cup Leaking	Service Portion Defective	Emergency Portion Defective
260	Fail	Pass	Pass	No defects found						
317	Fail	Pass	Fail						X	
269	Fail	Pass	Fail	X						
272	Fail	N/A	Fail			X			X	X
117	Fail	Fail	Pass	No defects found						
360	Pass	Fail	Fail	X				X		
367	Pass	Fail	Fail			X				
395	Pass	Fail	Fail			X			X	
249	Pass	Fail	Fail		X					
217	Pass	Fail	Fail	X	X		X			
143	Pass	Fail	Fail			X				

Two of the five cars (Fast car numbers 260 and 117) found defective by the manual test method passed the single-car air-brake test with no problems. This included the car (FAST car number 117) that failed both the manual and the controlled fully loaded train testing. It should be noted that this car failed the controlled fully loaded train testing only on the first night of testing, but passed on the second and third nights. One of the five cars (FAST car number 317) found defective by the manual test method required a service portion valve change in order to pass the single-car air-brake test. One (FAST car number 272) required a service and emergency portion valve change, as well as a broken auxiliary reservoir pipe that required welding (this car was not in the consist during controlled fully loaded train testing). A final one (FAST car number 269) required only minor leak repairs to pass the single-car air-brake test.

Of the six remaining cars that were identified with possible ineffective brakes during controlled fully loaded train testing at FAST, one (FAST car number 249) required only minor leak repairs to pass the single-car air-brake test, one (FAST car number 360) had to have a brake cylinder packing cup replaced (truck mounted brakes), one (FAST car number 217) had to have a cylinder pipe gasket replaced, and three (FAST car numbers 367, 395, and 143) had broken auxiliary reservoir pipes that required welding. One of these (FAST car number 395) also required a service portion valve change to pass the single-car air-brake test.

4. Conclusions and Recommendations

Both the proof-of-concept testing and the controlled fully loaded train testing demonstrated the ability of technology to distinguish between applied and nonapplied brakes for known braking conditions. This implies that it is also possible to make this distinction for unknown braking conditions when sound statistical methods are applied.

The data collected during the controlled fully loaded train testing was independently analyzed by two engineers using different methodologies. The cars identified as having ineffective brakes were the same in both cases. This implies that there may be multiple ways to analyze the data to produce reliable results.

The controlled testing helps validate the revenue service detector results that show a brake-related defect detection rate of approximately four times that of the manual inspection defect detection rate is possible using wheel temperature detectors. However, both methodologies indicate that a very small percentage of brake-related defects were actually present in the test fleet. Revenue service detector results that show several cars with a repeated cold-wheel condition over the course of multiple passes indicate a failure of the manual test to properly identify ineffective brakes. This could possibly be the result of testing the train in a static condition (manual inspection) as opposed to a dynamic condition (detector), as well as the possibility that the true revenue service hold-time of the brake system is not sufficient to provide an effective brake.

Another consideration when comparing results of the two methodologies is the fact that the manual test is performed with a 20-pound per square inch brake pipe reduction. When train brakes are used for train handling purposes in revenue service, brake pipes are reduced typically by 6–10 psi. This is what was seen in the revenue service testing and replicated in the controlled fully loaded train testing.

Results of single-car air-brake testing on the failed cars at FAST indicate that testing brakes in the dynamic condition may exacerbate problems that do not fully manifest themselves in a static environment. For example, small leaks in brake cylinder packing cups, piping, and fittings that may not affect piston travel and/or hold-times during the manual test may be amplified during dynamic testing. The effects of the small leaks during dynamic testing may negatively impact the nominally designed retarding force of the car’s braking system. Results also indicate the possibility of differences in brake valve function during static and dynamic operations.

Testing to examine the correlation between piston travel and applied shoe force shows that force can vary for constant piston travel when the brake rigging configuration is altered. This can be attributed to the action of the automatic slack adjuster common to modern railcars. The slack adjuster maintains constant piston travel as brake rigging changes occur. Brake rigging changes such as lever angularity and brake rod lengths, while not affecting piston travel (due to the action of the automatic slack adjuster), have a definite effect on shoe force. Therefore, proper piston travel does not ensure adequate shoe force.

Results from this limited testing indicate that wheel temperature detector technology has the capability to distinguish between effective and noneffective brakes. However, it is recommended that additional testing be conducted to further investigate the cause-and-effect relationship between brake system defects and relative wheel temperature.

5. References

Federal Railroad Administration, Department of Transportation, *Code of Federal Regulations*, Title 49 Part 200 – Part 299, Washington, DC.

Abbreviations and Acronyms

AAR	Association of American Railroads
CFR	Code of Federal Regulations
FAST	Facility for Accelerated Service Testing
TCR	track conditioning run
TTC	Transportation Technology Center (the site)
TTCI	Transportation Technology Center, Inc. (the company)
UP	Union Pacific Railroad