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# Service Stability Testing of Suspect Brake Equipment

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## Summary

Transportation Technology Center, Inc. (TTCI) tested air brake equipment removed from 43 cars suspected of causing multiple undesired emergency brake applications (UDEs) using industry established test methods and special tests designed to replicate short duration brake pipe pressure (BPP) fluctuations. The equipment removed from 13 of those cars failed the Single Car Air Brake Test (SCABT). Individual brake control valve stability performance was found to be inconsistent as evidenced by conflicting test results and a wide range of short duration BPP reduction rates that sometimes produced UDEs and other times did not.

Special service stability testing conducted at room temperature and in TTCI's cold room at temperatures between 15°F and 20°F showed that brake control valves are less stable when tested at cold temperature than at room temperature by an overall average of 1.1 psi/sec in the critical BPP reduction rate. None of the equipment produced UDEs in response to BPP fluctuations that were less severe than the BPP reduction associated with the SCABT service stability test.

Air in a train's brake pipe has sufficient momentum to generate fluctuations in the BPP pressure when subjected to the accelerations of train slack action. The path forward includes capturing data to quantify the BPP fluctuations associated with train slack action. The methods used to analyze data from the special service stability testing will be applied to the measured BPP fluctuations resulting from slack action. This will allow comparison between the magnitudes and durations of the BPP reductions from the service environment, the SCABT service stability test, and the stability thresholds for the brake valves tested.

The work described in this *Technology Digest* was conducted as part of a root cause analysis of UDEs under the Association of American Railroads' Strategic Research Initiative on Improved Brake System Performance.



**INTRODUCTION AND BACKGROUND**

Investigation of air brake equipment removed from cars suspected to have caused multiple undesired emergency brake applications (UDEs) in service showed that the majority of this equipment produced acceptable stability in relation to industry established test criteria.

Previous research examining the causes and mitigation methods for UDEs has been summarized in a previous *Technology Digest*.<sup>1</sup> One of the conclusions from past work was that most UDEs were caused by fluctuation of brake pipe pressure (BPP) due to slack action associated with train handling. It was also found that below 32°F condensing moisture in the brake pipe may contribute to UDEs.

Newer brake valves, such as the ABDX and DB20, include design features intended to make them less prone to UDEs. Older style valves (ABD and ABDW) can receive stabilization retrofits (ABDS and ABDWS) to improve their UDE performance. The Single Car Air Brake Test<sup>2</sup> (SCABT) includes a test of the service stability of the control valves by venting brake pipe pressure through a 0.136-inch diameter orifice for cars with up to 75 feet of brake pipe. The SCABT also includes an emergency application test by venting BPP through a 0.375-inch diameter orifice.

Until recently, identifying cars suspected of causing UDEs has been extremely difficult. As part of the AAR’s Asset Health Strategic Initiative, railroads are now sending consist lists of trains that experience UDEs to Railinc so that suspect cars that repeatedly appear in multiple trains with UDEs can be identified and inspected.<sup>3</sup>

**VALVE TESTING**

TTCI received and tested air brake equipment from 43 cars suspected of causing multiple UDEs. Regardless of the SCABT results during the railroad inspection, the brake equipment was removed from the car and sent to TTCI. Each set of service and emergency control valves removed from these cars was installed on TTCI’s single car test rack and subjected to SCABT and special service stability testing with BPP fluctuations. The test rack was configured to simulate a car with 52 feet of brake pipe for most tests and reconfigured to simulate a car with 79 feet of brake pipe when testing components removed from long cars.

Table 1 describes the equipment tested including a generic labeling used later in this *Technology Digest*. Service portions are not listed in Table 1 as they are much less likely to affect stability and could occur in many combinations with emergency portions.

**Table 1. Air Brake Equipment Tested**

<b>Equipment</b>	<b>Quantity</b>	<b>Label</b>
ABD Emergency Portions	8	1
ABDW Emergency Portions	5	2
ABDS or ABDWS Emergency Portions	4	3
ABDX or ABDXR Emergency Portions	8	4 or 5*
DB20 Emergency Portions	14	4 or 5*
DB20L Emergency Portions	3	N/A
#8 Vent Valve	1	N/A

\*The label for these valve types is intentionally ambiguous

**Single Car Air Brake Test**

Brake equipment from 13 of the 43 cars failed the SCABT at least once. Nine cars reportedly failed the SCABT during the railroad inspections including one #8 vent valve and one car that failed the initial service stability test but passed a subsequent identical test.

TTCI used an automated test device to conduct SCABTs through a 4-port adapter on the single car test rack. The automated 4-port SCABT is generally considered the most consistent method of conducting a SCABT, because the air pressures are controlled and measured by a computerized system at the pipe bracket rather than by a human at the end of the car. The SCABTs conducted by TTCI failed the valves from six cars, two of which were the same valves that failed the tests conducted by the railroads. TTCI testing confirmed the failure of the #8 vent valve, but could not confirm the failed service stability test reported from the railroad SCABT. The equipment from one car failed the TTCI SCABT service stability test, but it had previously passed the SCABT conducted by the railroad.

**Special Stability Testing**

TTCI conducted special stability testing of each set of control valves by installing a programmable pressure control device to the single car test rack. A series of time history input files were developed which reduced the BPP from a fully charged condition of 90 psi to a target pressure between 80 and 88 psi over a period between 50 and 500 msec. A minimum of 33 BPP reductions were provided to each set of brake valves. The parameters of each subsequent reduction were determined iteratively with the goal of producing an emergency application in approximately half of the tests.

A pressure transducer was installed at the pipe bracket to measure BPP as near as practicable to the brake valves. The signal from this transducer was digitized at 1,000 samples per second and digitally low-pass filtered at 100 Hz. The pressure time history was differentiated to produce a channel of the BPP reduction rate (psi/sec). The sign of this channel was adjusted so that positive values indicated an increase in the rate of

the BPP reduction. Moving averages were calculated on the BPP reduction rate channel using window sizes of 10, 25, 50, 75, and 100 msec. The maximum value of the moving average was calculated for each window size. In files where a UDE occurred, the moving average calculations were halted at the start of the emergency application. Figure 1 shows the time histories of the BPP and reduction rate from a single test. In addition, the moving average channel is shown for the 100 msec time window.

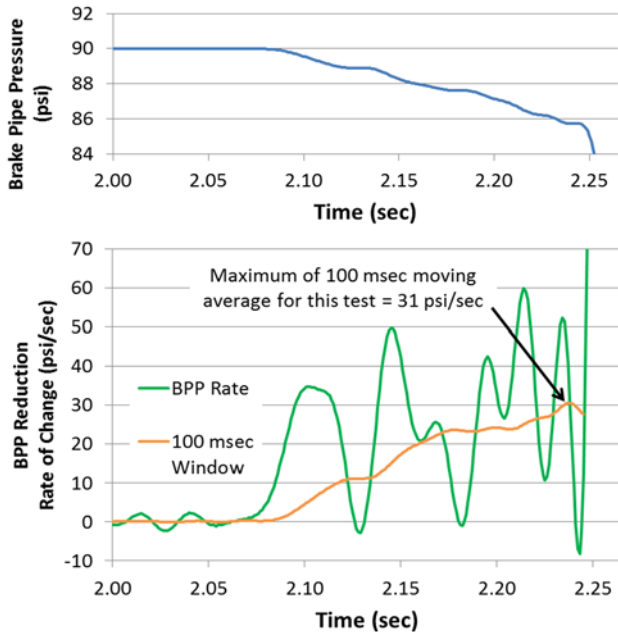


Figure 1. Time Histories from a Single BPP Reduction Test

For each set of brake valves, the maximum values of the moving average calculations were plotted for each BPP reduction and grouped according to whether or not a UDE occurred. In this way, a map of the stable, inconsistent, and unstable performance regions of each set of values was produced. Figure 2 shows an example map from one set of brake valves. The highest reduction rates that did not cause a UDE form the unstable threshold. Reduction rates above the unstable threshold will produce an emergency application. The lowest reduction rates that caused a UDE form the stable threshold or critical BPP reduction rate that can potentially produce a UDE. Between these thresholds lies a region of inconsistent performance.

In addition to the performance results from a set of valves, Figure 2 includes the measured results from BPP reductions associated with the SCABT service stability test at which the valve must remain stable and the SCABT emergency test at which an emergency application must occur. These values are included as a reference, but should not be considered as criteria for the

special stability tests, because the duration of the BPP reductions in the special stability testing is substantially shorter than in the SCABT.

It should be noted that the unstable threshold for some sets of valves as determined through this research effort exceeded the values produced by the SCABT emergency test over the short duration evaluated (up to 100 msec window). This is not cause for alarm, because these valves respond correctly to longer duration emergency applications as evidenced by their ability to pass the emergency test of the SCABT.

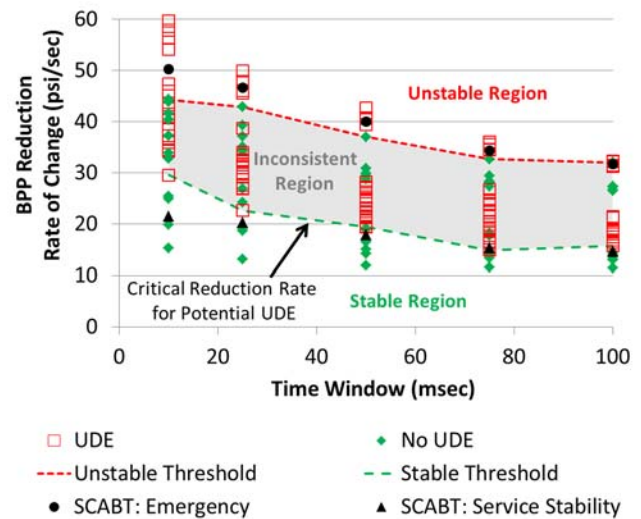
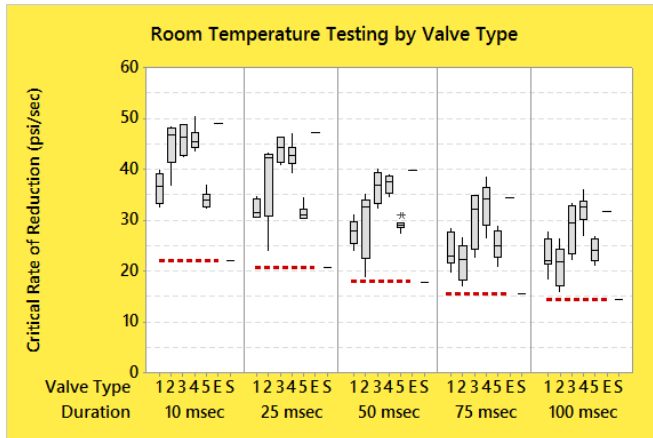


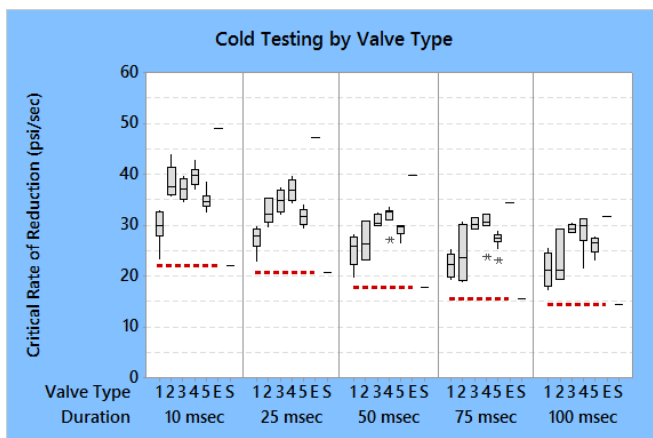
Figure 2. BPP Reduction Rate Map Example

Brake equipment was subjected to the testing and analysis described here at room temperature and again inside TTCI’s cold room between 15°F and 20°F after being stored in the cold room overnight to achieve a steady state temperature. Figures 3 and 4 are box plots that summarize the critical BPP reduction rates of the tested valves at room temperature and at cold temperature, respectively. For consistency, the brake equipment removed from long cars (DB20L and #8 Vent Valve) is not shown in these figures. Each box shows the 25th-, 50th-, and 75th-percentiles, and the whiskers show the range of the data points within 1.5 times the interquartile range from the edges of the box. Stars indicate outlier data. Valves are grouped by the generic labels listed in Table 1. The BPP reduction rates from the SCABT emergency and service stability tests are also shown for each time window as a reference, abbreviated as valve types “E” and “S” respectively. The SCABT service stability rates have been additionally emphasized with red dotted lines drawn on the figures.

Analysis of variance (ANOVA) was used to identify statistical differences between the stability of the different valve types considering the critical reduction



**Figure 3. Box Plot of Suspect Valves at Room Temperature**



**Figure 4. Box Plot of Suspect Valves at Cold Temperature**

rates from all moving average windows. Under room temperature test conditions, valve types 3 and 4 were more stable than valve types 1 and 5. Under cold temperature test conditions, valve types 3, 4, and 5 were more stable than valve type 1, and valve type 4 was more stable than valve type 5. Due to its relatively large variance in the results, valve type 2 was not found to be statistically different from any of the other valve types when considering the performance from a single ambient temperature condition. The relevance of comparisons of the different valve types in this study is somewhat limited due to the fact that these valves are under suspicion of causing UDEs, and therefore, their stability performance may not be representative.

When considered altogether, the valves were less stable at cold temperature compared to room temperature with a statistically significant change of 1.1 psi/sec in the critical BPP reduction rate. However, when comparing each type of valve to itself at different temperatures, only the type 4 valves showed a statistical decline in stability under cold conditions.

None of the brake equipment produced critical BPP reduction rates less than the SCABT service stability rate. This should perhaps not be surprising, because the special stability testing involved much shorter duration BPP reductions compared to the SCABT. The BPP reduction rates associated with short duration events in service are not currently well quantified, and thus criteria for the critical BPP reduction rates at different time durations has not been established.

Water intrusion appeared to affect the equipment from three cars. Though they tested fine at room temperature, they malfunctioned at cold temperature and could not be tested. It is possible that water intrusion occurred after the equipment was removed from the railcar and before being received by TTCI.

## CONCLUSION

SCABT and special stability testing of brake equipment removed from railcars identified as repeatedly causing UDEs have shown the following:

- None of the equipment produced UDEs in response to BPP fluctuations that were less severe than the BPP reduction associated with the SCABT service stability test. The characteristics of short duration BPP fluctuations resulting from slack action are not currently well defined.
- Many of the control valves produced inconsistent stability performance, as evidenced by conflicting results from multiple SCABTs and inconsistent responses to short duration BPP fluctuations.
- Brake control valves are less stable by an average of 1.1 psi/sec in the critical BPP reduction rate when tested at cold temperature compared to room temperature.

## PATH FORWARD

TTCI will quantify BPP fluctuations from train slack action to compare to the SCABT service stability BPP reduction rate and the critical rates identified herein.

## REFERENCES

1. Cummings, Scott and Alexander Keylin. "Train Handling Prior to Undesired Emergency Brake Applications in Warm Weather." *Technology Digest* TD-16-019. AAR/TTCI. Pueblo, CO. 2016.
2. Association of American Railroads. *AAR Manual of Standards and Recommended Practices*. Section E. Standard S-486 "Code of Air Brake System Tests for Freight Equipment – Single Car Test." Adopted 1991; Last Revised 2013.
3. Association of American Railroads. Maintenance Advisory MA-0146. 2015.

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