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Laboratory Testing of Brake Cylinder Pressure Maintaining Valves

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Summary

Transportation Technology Center, Inc. (TTCI) tested the performance of freight car brake control valves equipped with a brake cylinder pressure maintaining (BCPM) feature. BCPM valves limit the decrease in pressure that results from a leak in the brake cylinder over a range of pressure values. These valves maintain higher pressures in the brake cylinder during heavy braking when compared to a standard valve's Quick Service Limiting Valve (QSLV) feature. During minimum service or light braking applications, there is a smaller difference between the BCPM valve and the standard valve. This *Technology Digest* compares these two types of valves and demonstrates that BCPM valves do not require a large increase in the airflow in the brake pipe while functioning.

Data was acquired in the air brake laboratory at the Transportation Technology Center (TTC). The test followed a predetermined test matrix that includes different control valves, brake cylinder leakage rates, brake pipe leakage rates, vendor configurations, and braking methods. The data was post-processed and analyzed to determine the effectiveness of BCPM valves compared to standard valves. The data demonstrated that BCPM valves can maintain brake cylinder pressure with leakage rates as high as 5 psi per minute with no apparent negative consequences on the brake system performance.

This investigation was undertaken by TTCI under the Association of American Railroads' Strategic Research Initiative on Brake Systems.

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INTRODUCTION

TTCI conducted a series of tests in the air brake laboratory at TTC to assess the functionality of freight car brake control valves equipped with a brake cylinder pressure maintaining feature. A performance comparison was made between the control valves of two different vendors and a standard set of control valves without the BCPM feature.

BACKGROUND

Trains utilize an open loop pneumatic system to control the pressure inside the brake cylinder when the brakes are applied. The brake cylinder pressure results from a brake pipe reduction and the equalization that occurs between the auxiliary reservoir and the brake cylinder. The lack of feedback control in the system does not allow control valves to compensate for leakage that can occur in the brake cylinder. This may result in a decrease in the brake force during applications.

Standard brake valves contain a Quick Service Limiting Valve (QSLV) that maintains brake cylinder pressure to about 10 psi in an event that leakage occurs. This can result in an approximate 85 percent decrease in brake force in the case of a full service application. Current standards allow up to a 1 psi per minute leakage rate.[1] Constant braking over long grades with the maximum allowable leakage rate can cause the train to reach this minimum brake force scenario.

BCPM valve systems were designed to limit the decrease in pressure that can result from a leak in the brake cylinder over a range of pressure values.[2] The feature is designed to detect a leak and maintain the pressure at a higher level than the 10 psi threshold that activates the QSLV.

TEST DETAILS

The air brake laboratory at TTC consists of a 26-L brake valve that controls the charging and brake applications of a freight train air brake system for 150 cars. The length of the consist can be adjusted by closing an angle cock at the desired car location. The valves of individual cars can also be cut-in or cut-out of the system. The system contains intermediate pressure taps that are utilized to install pressure transducers and simulate leaks at various locations on the train. Flow meters are present at the beginning of the system and precede the first car of the consist.

The test procedure was designed to record the change in brake cylinder and pipe brake pressure for the different types of brake valves when subjected to various conditions. A predetermined test matrix was created with varying parameters that consisted of brake valve type, induced brake cylinder leakage, induced rear end brake pipe leakage, and braking application method. Measured parameters are the flow rate at the head of the train, the brake pipe pressure at the head and rear end of the train, and the brake cylinder pressure at the last 20 cars of the train. Tests were run with all 150 control valves cut-in.

Brake cylinder leaks were created by placing bushings into valves at the piping of the brake cylinders. The flow rate of the leak was limited by the diameter of the hole drilled in the bushing. The holes were created to have the appropriate leakage rates of 1, 2, 3, and 5 psi/min with 25 psi in the brake cylinder. Table 1 displays the leakage rates of an average brake cylinder for each brake cylinder leak. Brake pipe leaks were created at the rear end of the system by placing 3/8-inch elbows with a pneumatic fitting into the brake pipe. For the specified tests, leaks were placed in the brake pipe at the rear end of the train to create roughly a 15 psi gradient between the front and back of the consist and a flow rate of approximately 40 cubic feet per minute (cfm).

Table 1. Average Brake Cylinder Leakage Rate Values

Nominal Brake Cylinder Leakage Rate (psi/min) at 25 psi Brake Cylinder Pressure	Average Measured Brake Cylinder Leakage Rate (PSI/min)
1	1.00
2	2.06
3	3.04
5	4.71

Each type of brake control valve (standard/non-BCPM, Vendor A, Vendor B) was subjected to the various brake cylinder and brake pipe leaks. Pressure data was collected from the last 20 cars of the consist for each test. Tests were conducted with all non-BCPM valves, 20 Vendor A BCPM valves at the end of the train, 20 Vendor B BCPM valves at the end of the train, 10 BCPM valves from each vendor (20 total BCPM valves) in alternating order, and a final test with all 40 vendor BCPM valves at the rear of the train in alternating order.

The different types of braking methods used in the tests were deemed standard, cycle, and emergency. Each braking method began with the train in steady state and the brakes released. The standard braking procedure began with a minimum service reduction of 7 psi. The application was then increased to 10 psi, 15 psi, and full service (~26 psi). At each increment, the application was held a minimum of 10 minutes to allow equilibrium to be reached in the system. The test was ended after the final waiting period. The cycle braking began with a minimum service application and a 10-minute waiting period. The brakes were then released for 1 minute. A reduction was then performed with the target of reducing the rear end pressure at least 7 psi below the pressure it had attained during the 1-minute release. After again leaving the brakes applied for 10 minutes, the short release and reapplication were repeated, and the test ended after the equilibrium waiting period. The emergency test was performed by making an emergency application and waiting for 30 minutes.

During each test, the data collection began with the consist charged and in equilibrium with the leaks in their appropriate locations. Data collection ended after the final waiting interval when equilibrium was achieved in the system. Raw data from each test was then post-processed to obtain the results. Figures 1 and 2 show examples of a standard test run and a cycle test run. Figure 1 shows standard test run No. 26, and Figure 2 shows cycle test run No. 43; both test runs had 3 psi/min cylinder leakage rate.

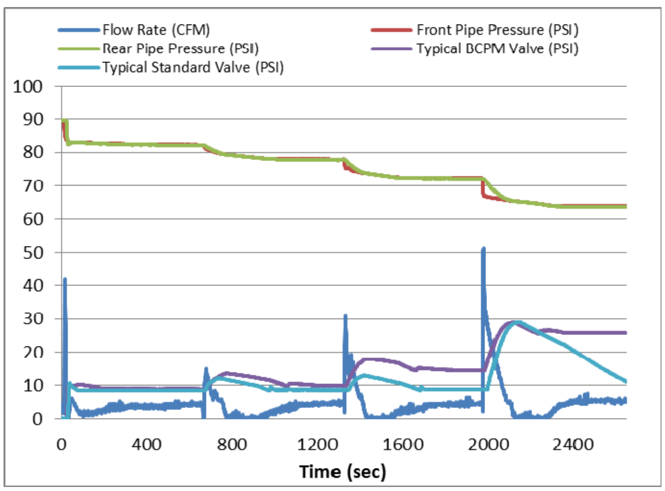

Figure 1. Standard Test Run No. 26

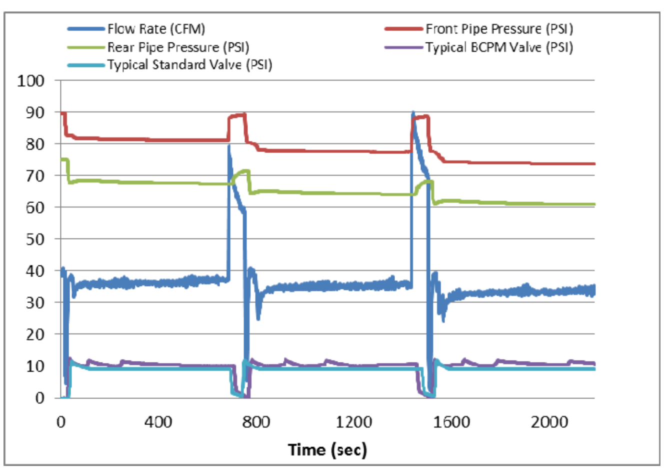

Figure 2. Cycle Test Run No. 43

RESULTS

The test matrix produced a total of 62 runs from a combination of five induced brake cylinder leakage rates (0,1,2,3,5 psi/min), two induced brake pipe leakage rates (0 and 40 cfm), five vendor configurations (standard or non-BCPM valves, 20 Vendor A valves, 20 Vendor B valves, alternating 10 Vendor A/ 10 Vendor B valves, and alternating 20 Vendor A/ 20 Vendor B valves), and three braking methods (standard, cycle, emergency).

The majority of the tests showed that Vendor A and Vendor B BCPM control valves performed their functions as expected. The brake cylinder pressure was maintained with leakage rates up to 5 psi/min during heavy braking with no apparent negative consequences on the performance of the brake system.

Figure 3 is a plot of flow rate versus leakage rate during the standard procedure tests with the valves at steady state under a full service brake application and is grouped by vendor. The plot shows that although flow rate increases by a few cfm with larger leakage rates, there is little difference between the standard and BCPM valves. This indicates that BCPM valves would not negatively influence the brake system by drawing air at a much higher rate from the brake pipe compared to the current standard valves.

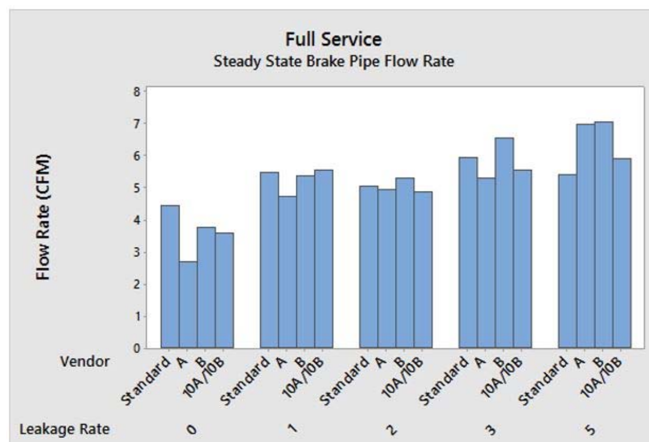

Figure 3. Plot of Flow Rate (CFM) grouped by Vendor and Leakage Rate (PSI/min)

In Figure 4, the results of 20 standard procedure test runs are summarized with brake cylinder pressure plotted against leakage rate with the valves at steady state under a full service brake application. Tests involving a full service application are displayed, because this type of application can be reached with greater consistency during testing, and heavy braking creates the largest difference in pressure maintaining between BCPM valves and standard valves. The data demonstrates that in all cases the average pressure was maintained at a higher level using BCPM valves than using the standard valves.

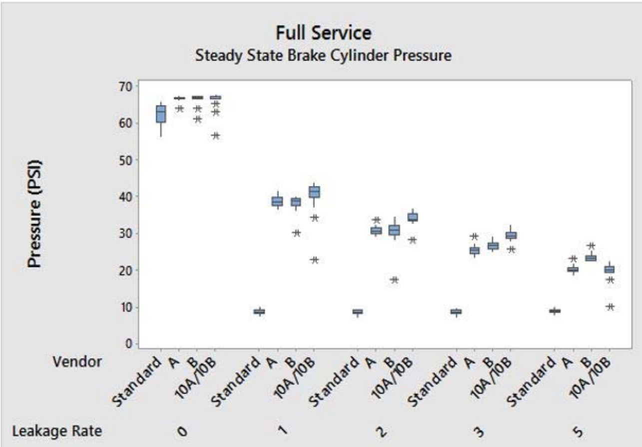

Figure 4. Boxplot of Brake Cylinder Pressure (PSI) grouped by Vendor and Leakage Rate (PSI/min)

Many tests that involved light braking applications, at or near minimum service, resulted in low brake cylinder pressures of ~10 to 12 psi. It was difficult to distinguish the difference in performance between the QSLV of standard control valves and the BCPM feature, because both features are activated at these pressures. These relatively low brake cylinder pressures are thought to be due to the lack of brake rigging in the air brake laboratory. The pistons extend until they hit a solid stop at an average of 8 1/8 inches of piston travel. This is slightly different than the situation in a normal freight car when the piston travel varies according to the brake cylinder pressure due to the friction and spring action of the rigging. Thus, in a real application on a freight car, a minimum service application is expected to produce about 15 psi brake cylinder pressure. The volumes in the air brake laboratory are correct as evidenced by a 65 psi brake cylinder equalization pressure.

Several exceptions to the general behavior of the BCPM valves occurred with one of Vendor B valves. The control valve experienced two separate instances where the pressure in the brake cylinder released suddenly and unexpectedly. In Figure 5, the valve in Car 149 experienced a slow leak that dropped it below the QSLV pressure range during the first brake application. The brake cylinder pressure then released completely shortly after the second brake application. This same valve also produced an unexpected complete sudden release during another cycle braking test run. At the conclusion of the two test runs that demonstrated odd behavior, the brake rack was subjected to an emergency application, recharged, and the test was repeated without finding similar behavior. The unexpected pressure release appeared to be intermittent behavior.

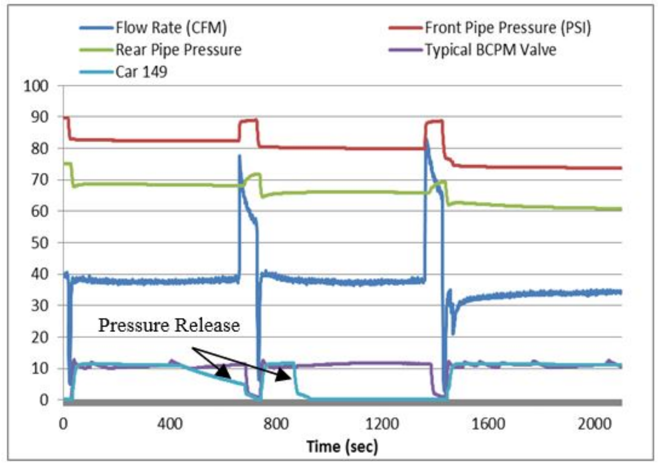

Figure 5. Time History of Unusual Brake Cylinder Pressure Releases

Another control valve from Vendor B experienced several instances where pressure from the brake cylinder leaked down to a lower level than the other BCPM valves in the test. Despite the discrepancy between this valve and the others, the valve did not allow the brake cylinder pressure to leak below the QSLV level where standard valves begin to maintain the pressure.

CONCLUSION

BCPM valves performed as expected to limit the decrease in pressure that can result from a leak in the brake cylinder over a range of pressure values. TTCI reached this conclusion based on results from 62 tests in the air brake laboratory at TTC with a variety of control valves, brake cylinder leakage rates, brake pipe leakage rates, vendor configurations, and braking methods. Brake cylinder pressure was maintained at higher levels than the QSLV in standard valves during heavy braking, with leakage rates as high as 5 psi/min with no apparent negative consequences on the brake system. Brake applications at levels less than full service resulted in smaller differences between the pressure maintaining ability of BCPM and standard valves.

REFERENCES

1. Association of American Railroads. *Manual of Standards and Recommended Practices*, Section E. Standard S-486 "Brake Cylinder Leakage Test." Washington, DC. Revision 2014.
2. Wright, E. "Improving Safety and Lifecycle Costs with Brake Cylinder Maintaining." The *Air Brake Association 2014 Annual Technical Conference*, Montreal, Quebec. 2014.