U.S. Department
of Transportation

**Federal Railroad
Administration**

SAFETY EVALUATION OF TSM PROTOTYPE ELECTRONICALLY CONTROLLED PNEUMATIC TRAIN BRAKE SYSTEM ON BRAKE RACK

Office of Research and
Development
Washington, D.C. 20590

DOT/FRA/ORD-99/08

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Final Report

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16. Abstract

Performance standards for Electronically Controlled Pneumatic (ECP) freight brake systems for use on the North American railroads are being developed by working groups composed of personnel from the railroad industry, the railroad supply industry, and AAR technical staff. Draft specifications (S-4200) have been developed covering system performance, head-end power, communications, connectors, and cable. The performance specification is titled "Performance Requirements for Testing Electrically Controlled Pneumatic (ECP) Cable-Based Freight Brake Systems" and designated S-4200 (an equivalent process is under way to develop performance requirements for radio-based ECP under S-4300). This specification is still under development, and a Failure Modes, Effects and Criticality Analysis (FMECA) remains to be made on the final version.

Upon completion of this set of tests, engineers determined that the TSM ECP brake equipment was suitable for installation on the FAST train. Although the TSM ECP brake equipment did not fully comply with the May 1997 version of S-4200, it does satisfy all the safety oriented requirements of this specification. TSM will be required to meet all provisions of the final specification when adopted by the Association of American Railroads.

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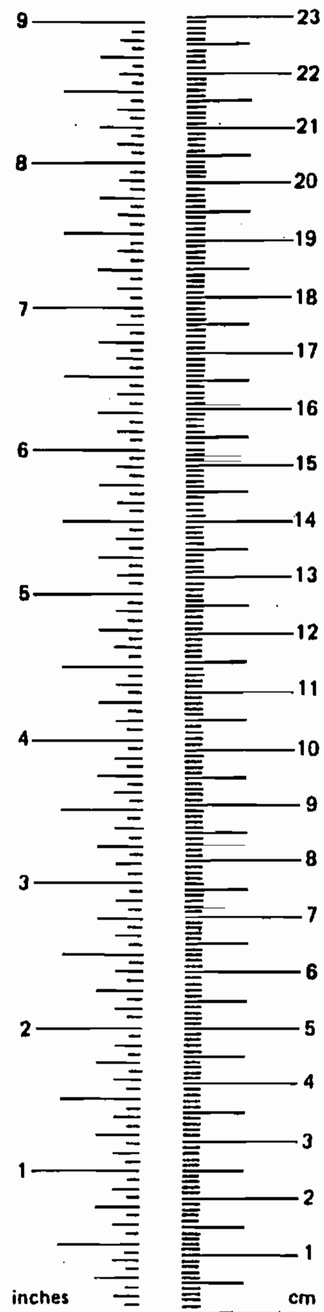
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

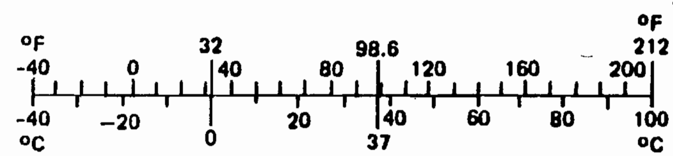
Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.50	centimeters	cm
ft	feet	30.00	centimeters	cm
yd	yards	0.90	meters	m
mi	miles	1.60	kilometers	km
		AREA		
in^2	square inches	6.50	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.80	square meters	m^2
mi^2	square miles	2.60	square kilometers	km^2
	acres	0.40	hectares	ha
		MASS (weight)		
oz	ounces	28.00	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.90	tonnes	t
		VOLUME		
tsp	teaspoons	5.00	milliliters	ml
Tbsp	tablespoons	15.00	milliliters	ml
fl oz	fluid ounces	30.00	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.80	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

* 1 in. = 2.54 cm (exactly)



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.40	inches	in
m	meters	3.30	feet	ft
m	meters	1.10	yards	yd
km	kilometers	0.60	miles	mi
		AREA		
cm^2	square centim.	0.16	square inches	in^2
m^2	square meters	1.20	square yards	yd^2
km^2	square kilom.	0.40	square miles	mi^2
ha	hectares (10,000 m^2)	2.50	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.10	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	36.00	cubic feet	ft^3
m^3	cubic meters	1.30	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius* temperature	9/5 (then add 32)	Fahrenheit temperature	°F



Executive Summary

Performance standards for Electronically controlled Pneumatic (ECP) freight brake systems for use on the North American railroads are being developed by working groups composed of personnel from the railroad industry, the railroad supply industry, and AAR technical staff. Draft specifications (S-4200) have been developed covering system performance, head-end power, communications, connectors, and cable. The performance specification is titled "Performance Requirements for Testing Electrically Controlled Pneumatic (ECP) Cable-Based Freight Brake Systems" and designated S-4200 (an equivalent process is under way to develop performance requirements for radio-based ECP under S-4300). This specification is still under development, and a Failure Modes, Effects and Criticality Analysis (FMECA) remains to be made on the final version.

Upon completion of this set of tests, engineers determined that the TSM ECP brake equipment was suitable for installation on the FAST train. Although the TSM ECP brake equipment did not fully comply with the May 1997 version of S-4200, it does satisfy all the safety oriented requirements of this specification. TSM will be required to meet all provisions of the final specification when adopted by the Association of American Railroads.

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1.0 INTRODUCTION

The Transportation Technology Center, Inc., a subsidiary of the Association of American Railroads (AAR), with support from the Federal Railroad Administration's Office of Research, has been developing performance standards for Electronically Controlled Pneumatic (ECP) freight brake systems for use on the North American railroads. The standards are being developed by working groups composed of personnel from the railroad industry, the railroad supply industry, and AAR technical staff. Draft specifications have been developed covering system performance, head-end power, communications, connectors, and cable. The performance specification is titled "Performance Requirements for Testing Electrically Controlled Pneumatic (ECP) Cable-Based Freight Brake Systems" and designated S-4200 (an equivalent process is under way to develop performance requirements for radio-based ECP under S-4300). This specification is still under development, and a Failure Modes, Effects and Criticality Analysis (FMECA) remains to be made on the final version.

2.0 OBJECTIVES

When S-4200 and the associated ECP specifications are finalized, they will be used to certify a manufacturers ECP brake system for use in interchange service on the North American railroad network. To attain conditional approval for a cable-based ECP system, a manufacturer must apply to the AAR Braking Systems Committee for authority to test. Given successful completion of those tests, the Committee will consider granting conditional approval for the system. Assuming that trouble free service is obtained, then the Committee can raise the approval limit in steps until finally an unconditional approval is granted.

Technical Services and Marketing Inc. (TSM) supplied the AAR with 50 ECP brake units to be tested first on the AAR's brake rack, and then installed on the train at the Facility for Accelerated Service Testing (FAST) at the Federal Railroad Administration's (FRA) Transportation Technology Center (TTC), Pueblo, Colorado. The emphasis of the rack testing was to verify that the TSM system was safe to use prior to installation of the FAST train.

The original brake rack testing of the TSM ECP brake units was performed in accordance with the preliminary ECP Brake Performance Specification S-4200, dated May, 1997 (see copy in appendix).

3.0 DESCRIPTION OF EQUIPMENT

The TSM system consists of a Car Control Device (CCD) and a manifold. The manifold contains the solenoid valves and pressure transducers which are used to fill and vent the brake cylinder and monitor brake pipe and reservoir pressure. The manifold is mounted between the pipe bracket and the service portion of the control valve. When the ECP system is energized, the manifold cuts off communication between the service portion and the brake cylinder, but the service portion continues its function of charging the reservoir. If the emergency portion is retained, then the car can operate in either an ECP train or in a conventionally braked train. This is known as an "overlay" ECP brake system. If the emergency portion is removed and replaced with a blanking plate, then the car can only operate in ECP equipped trains and is known as a stand alone ECP system. The version tested by TTC was a "stand alone" system.

The CCD is a separate box containing the computer, battery, battery charger, and other electrical components which form the "brains" of the car brake system. The CCD can be mounted anywhere on the car, but is usually in close proximity to the manifold.

The system is controlled by the head end unit (HEU) which is mounted on the top of the engineer's control stand. The HEU consists of a control box which has push buttons and soft keys. The service application and release button is mushroom shaped; pulling the button releases the brake, and pushing the button applies the brake. Brake applications are made as a percent of full service, with full service being a 100-percent application, a minimum service being a 15-percent application, and an emergency being a 120-percent application. The brake can be applied and released in 1 percent increments from 0 to 100 percent, or if the button is held, the application or release will continuously change up or down. The other push button is for emergency application, and it is caged to prevent accidental contact. The soft keys provide for minimum service, full service, and direct release. They are also used when initializing the train brake system. The HEU also has a flat screen which is used to inform the engineer of the status of the train brake system. The readout includes the brake pipe pressure on the last car, the brake command in effect, and any error messages.

The car brake systems are connected to each other by a shielded two-conductor No.8 gage cable. The cable carries both power and signal. Power at the locomotive is 230 Volts direct current, and it is provided by a power supply connected to the locomotive batteries. The cable between cars is connected using a Conomac connector, which is similar to a welding connector. This connector was used as a temporary connector until the AAR standard connector was developed. The Conomac connector's drawbacks are the exposed electrical contacts and the lack of a positive locking feature to keep the connectors together (the Conomac is held together by friction alone). The connector was simulated on the 150-car test rack by using an appropriate resistance in the cable junction boxes between each of the car racks.

The communications protocol is LonWorks® by Echelon. This protocol was chosen by the AAR as the standard for cable-based ECP brake system communication. LonWorks® is an off-the-shelf protocol widely used in applications such as in controlling building environments and in railroad transit applications.

The system allows the engineer to directly control the brake cylinder pressure on every car in the train. The brake pipe is used only to charge the reservoirs, even during brake applications. This allows the system to maintain full reservoir pressure at all times (except immediately after a brake application, when the reservoirs are drawing on the brake pipe to recharge), and it allows the CCDs to maintain brake cylinder pressure even if moderate brake cylinder leakage is present. If a CCD cannot provide the brake cylinder pressure commanded by the HEU, then that CCD will send an error message which will be displayed on the HEU. If the communications is disrupted, the system automatically goes into emergency, without venting the brake pipe, which allows for maintaining brake cylinder pressure even if some brake cylinder leakage is present. Automatic electric emergencies also result from loss of brake pipe pressure or reduction of operative brakes to less than 85 percent.

3.1 Installation of Equipment

Fifty TSM manufactured ECP brake CCDs were installed on the 150-car brake rack located at the TTC. The TSM CCDs were installed on every third air-brake control valve. Unequipped air-brake control valves were cut out. This setup resulted in the equivalent of a 7500-foot train comprised of fifty 150-foot cars.

The TSM ECP brake CCD is a two-piece device. The CCD manifold was installed between the pipe bracket and the pneumatic service valve portion. The CCDs were mounted near the manifolds on the brake rack support structure. The pneumatic emergency portion was completely removed and replaced with a blanking plate. In this configuration, the brake system functioned as a "stand alone" ECP brake system as defined in S-4200. Had the pneumatic emergency portion been retained, then the system would operate as an overlay system, which allows operation as a conventionally braked train when the ECP system is shut off. Operation in overlay or stand alone modes is identical as far as ECP operation is concerned.

The emergency reservoir and auxiliary reservoir on car 50 were connected with a 0.75 inch inside diameter pipe. This was done to simulate the performance of a brake system with a single 6,000 cubic-inch volume reservoir.

4.0 TESTS AND TEST RESULTS

The test plan consisted of testing to Sections 4 and 5 of the S-4200 version dated May,1997. Section 4 describes the single car test rack requirements, and Section 5 describes the performance requirements during testing on an AAR approved 150-car test rack. The performance requirements cover the normal operation of the system plus the required operation of the system when faults occur.

4.1 Full-Service Application and Release Test

A Full-Service Brake Application Test was made in accordance with Section 4.2 of S-4200, except that the test was performed on the 150-car test rack rather than on a single car test rack. The test must result in a full-service brake cylinder pressure of 64 pounds per square inch gauge (psig), and it must be reached within 10 seconds and maintained at ∀2 pounds per square inch (psi) for 10 seconds. Figure 1 shows all instrumented units reaching a full-service brake cylinder pressure of 64 psig in under 7 seconds. Figure 1 also shows that the brake cylinder pressure is developed simultaneously in all units, regardless of position in the train.

After 20 seconds, a full release was commanded. The brake cylinder pressure of each unit should be less than 5 psig within 15 seconds from the time the release is commanded. Figure 1 shows that each instrumented unit reached a brake cylinder pressure of less than 5 psig within 10 seconds of the time a full release was commanded. Figure 1 also shows that brake cylinder pressure is vented uniformly throughout the train.

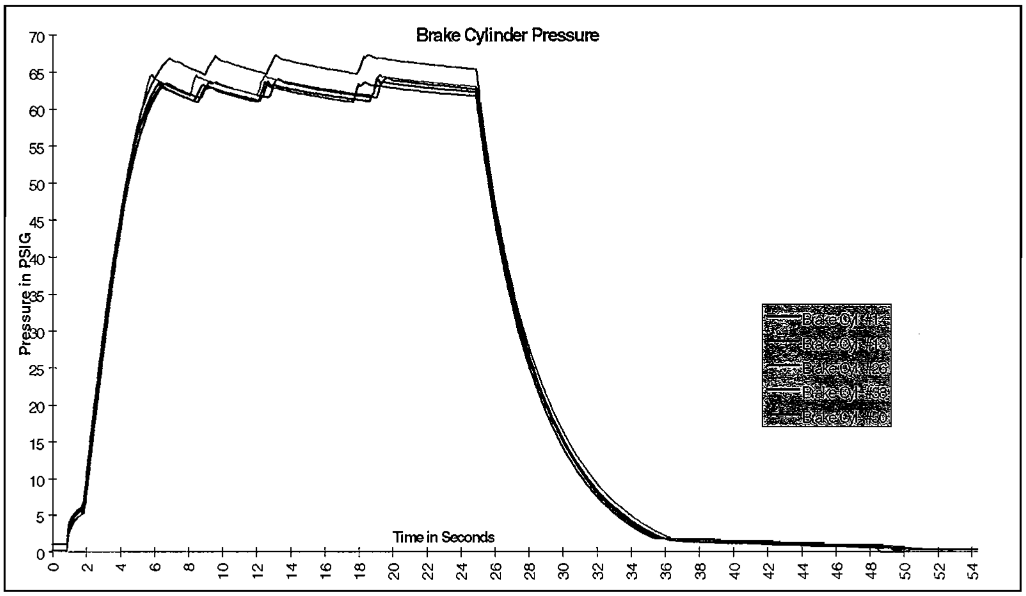

Figure 1. Brake Cylinder Pressure during Full-Service Application

4.2 Minimum Service Application and Release Test

Minimum service requirements were tested in accordance with Section 4.1 of S-4200, except that the test was performed on the 150-car test rack rather than on a single car test rack. When the cars on the test rack were fully charged, a minimum service brake application was commanded. Figure 2 shows the brake cylinder pressure for the first and last car in the brake rack. This test requires that the brake cylinder pressure for each unit be 9.6 psig ∀ 2 psi. Figure 2 shows over-pressure in the brake cylinder of less than 1 psi occurring initially. After 2 seconds, the brake cylinder pressure stabilized within the specified tolerances. This over-pressure condition is undesirable and is being addressed by the equipment manufacturer.

After 20 seconds, a full release was commanded. The brake cylinders vented to the atmosphere and all brake cylinder pistons fully retracted.

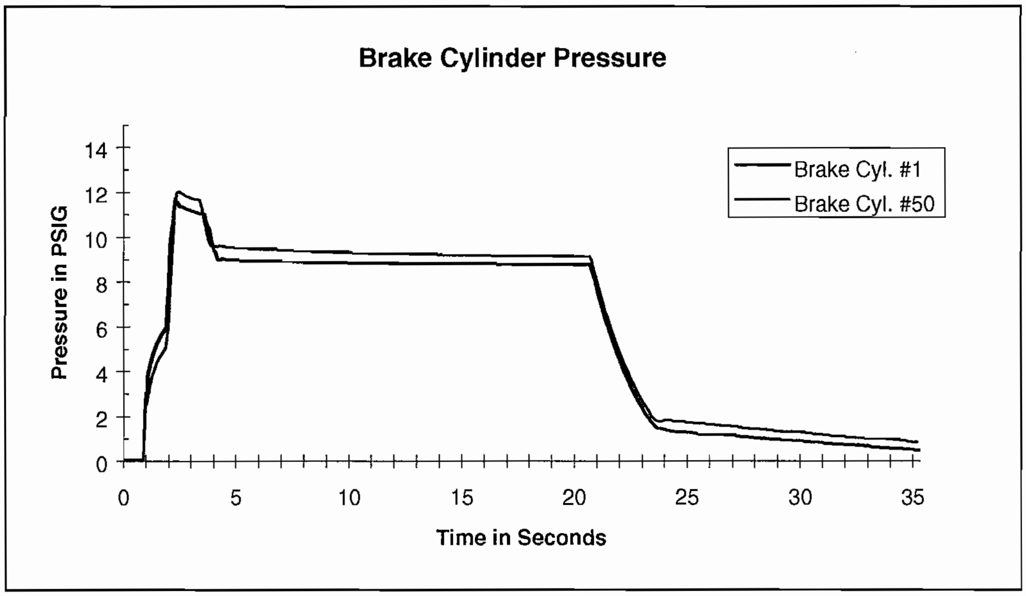

Figure 2. Brake Cylinder Pressure during Minimum-Service Application

4.3 Emergency Application

Emergency brake application was tested in accordance with Section 4.3 of S-4200, except that the test was performed on the 150-car test rack rather than on a single car test rack. An emergency brake application was commanded immediately after a release from full service, as specified in S-4200. The brake cylinder pressure of each unit should have a pressure of 76 psig ∀ 2 psi within 10 seconds. Figure 3 shows the brake cylinder pressure for the first and last unit in the brake rack. Unit 1 required 20 seconds to reach the target brake cylinder pressure, which does not satisfy the performance requirements. This is because the version of the TSM system under test draws all of its air supply from the 2,500 cubic-inch service reservoir only. The full emergency brake cylinder pressure lagged because the reservoir was still not fully recharged after the previous full service application. A straight-away emergency application with fully charged reservoirs would have met the required brake cylinder pressure within the required time. Unit 50 reached the target brake cylinder pressure more rapidly than the other ECP brake units because the emergency and auxiliary reservoirs on unit 50 were piped together, providing a larger 6,000 cubic-inch volume of compressed air to fill the cylinder.

Other manufacturers of ECP equipment use the 3,500 cubic-inch emergency reservoir, and stand alone systems in the future will likely use the entire 6,000 cubic-inch reservoir. Both of these options will improve system performance when an emergency is commanded immediately after a full service.

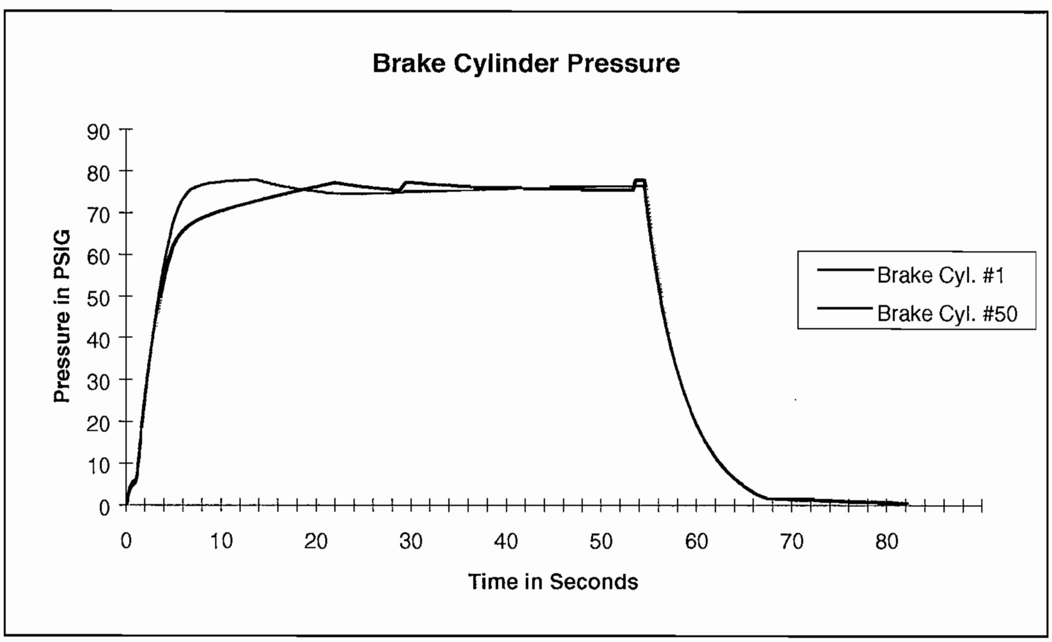

Figure 3. Brake Cylinder Pressure during Emergency Application

4.4 Graduated Application and Release

The Graduated Application and Release Test was performed in accordance with Section 5.2 of S-4200. When the test rack was fully charged, a minimum service (15% of full service) brake application was commanded. The brake command was reduced to 10 percent of full service. Every 5 seconds, the commanded brake application was increased by 10 percent of full service until a full-service brake application was reached. Then the commanded brake application was reduced by 10 percent of full service at 5-second intervals until the brakes were fully released. Figure 4 shows the brake cylinder pressure of the first and last brake units on the brake rack during this test. The equipment under test satisfied the graduated application and release performance requirements.

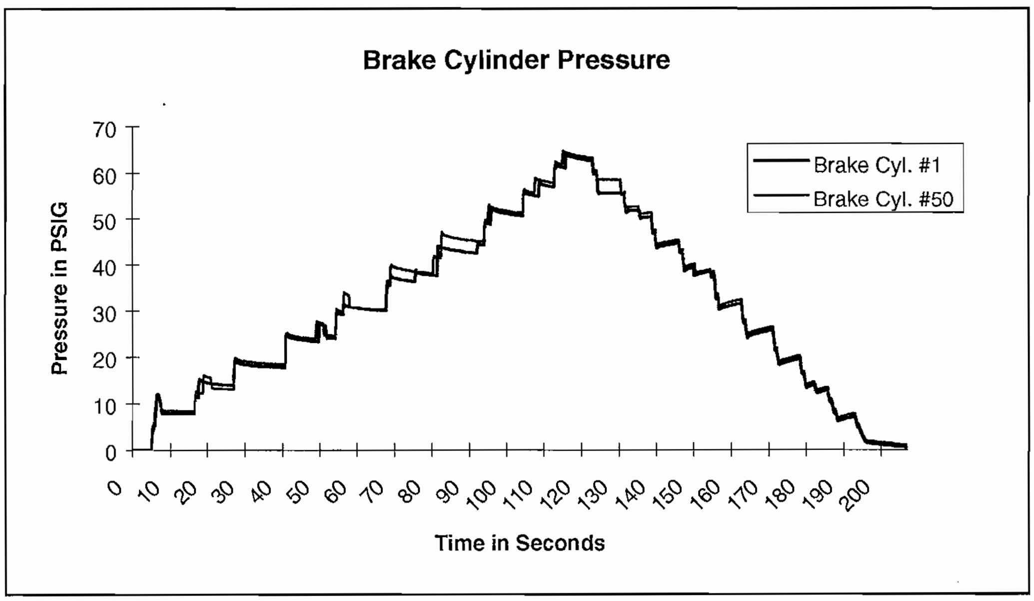

Figure 4. Brake Cylinder Pressure during Graduated Application Test

4.5 Repeated Full-Service Brake Application Test

The Repeated Full-Service and Release Test was performed in accordance with Section 5.3 of S-4200. The 50-car test rack was charged to 90 psig and an initial full-service application was made. When the first car brake cylinder pressure reached 64.0 psig, a full release was commanded. Fifteen seconds after the last car began to release another full-service application was commanded. Figure 5 shows the brake cylinder pressures during this test sequence for the first and last brake units on the rack. The repeated full-service brake application requirements are satisfied. Note that a conventional brake system is not capable of this level of performance, in that the second full service application would not reach full service brake cylinder pressure, especially on the last cars of the train.

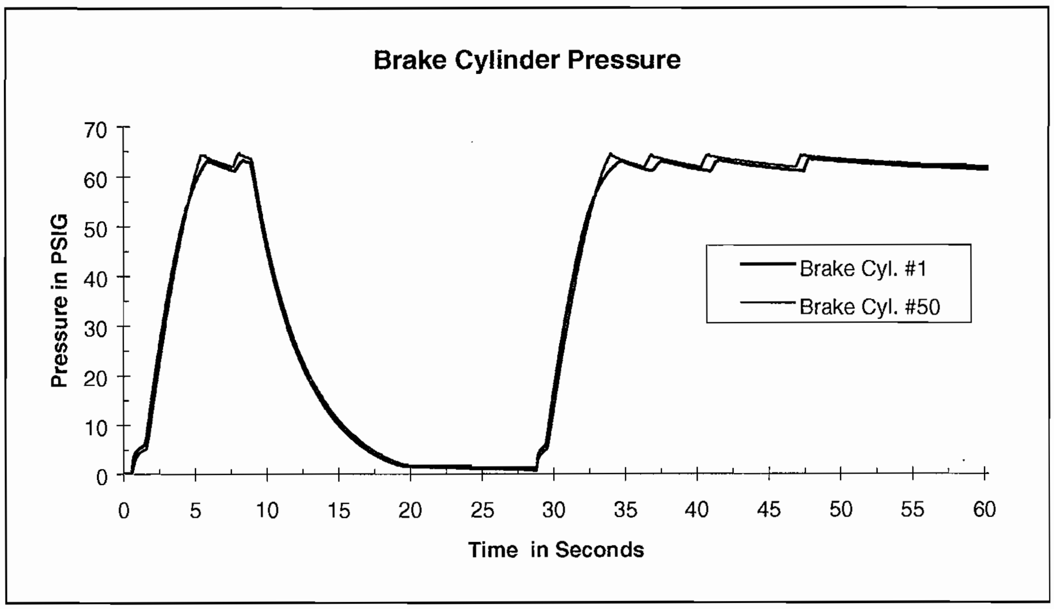

Figure 5. Brake Cylinder Pressure during Repeated Full-Service Application Test

4.6 System Loss of Communication Test

The System Loss of Communication Test was performed in accordance with Section 5.4.1 of S-4200. The ECP brake system on the 50-car test rack was charged to 90 psig. The communication network was disconnected between cars 27 and 28. The rear segment of the train made an emergency brake application 3.2 seconds after communications were interrupted, followed two seconds later by the front segment. The brake cylinder pressures of the first and last cars are plotted in Figure 6 in order to show timing of the system to the loss of communication fault. Since this test was run, TSM has made a correction to their software which has eliminated the time lag between the front and rear portions of the train.

All cars maintained a brake cylinder pressure of 74 psig for one hour and then the CCDs entered power conservation mode.

The system performed in an appropriate manner to a loss of network communication fault.

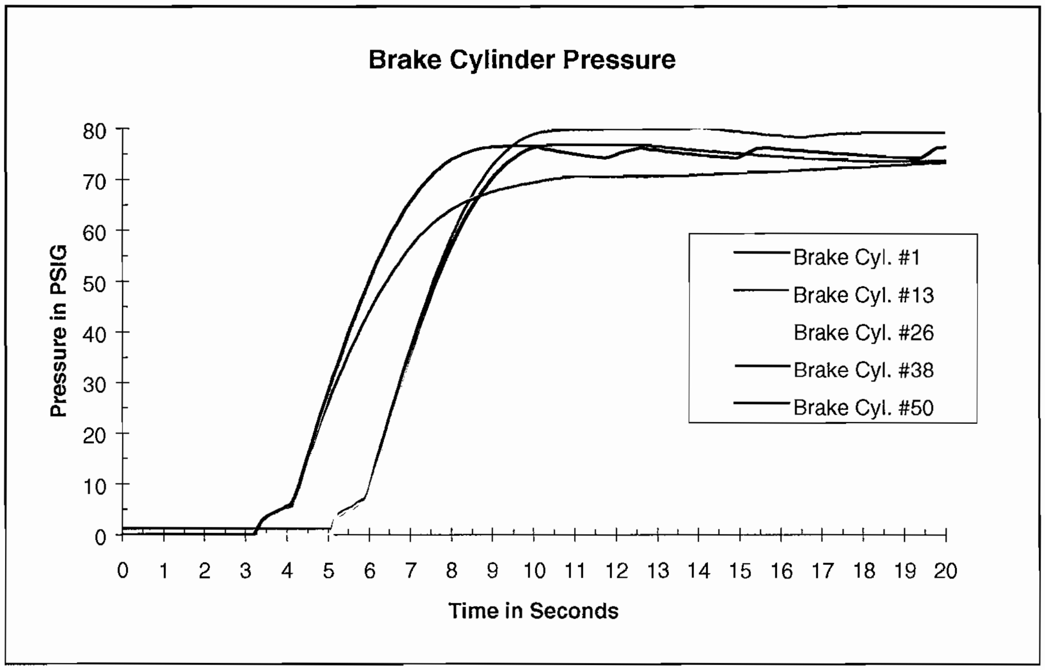

Figure 6. Brake Cylinder Pressure during Loss of Communication Test

4.7 Loss of Communication at Multiple Locations

The Loss of Communication at Multiple Locations Test was performed in accordance with Section 5.4.2 of S-4200. The ECP brake system on the 50-car test rack was charged to 90 psig. The communication network was simultaneously disconnected between cars 25 and 26, and between cars 38 and 39. All three segments of the train made an emergency brake application within 3.8 seconds after communications was interrupted.

This satisfies the requirements of S-4200 to a multi-point communication failure.

4.8 Loss of Communication to a Single CCD

The Loss of Communications to a Single CCD Test was performed in accordance with Section 5.4.3 of S-4200. A full-service brake application was commanded and held for 20 seconds. The communication line to car 1 was disconnected from the network. The CCD vented the brake cylinder to the atmosphere 3 seconds after it was disconnected. Also, the HEU reported that the CCD on car 1 was not functioning. Figure 7 shows the brake cylinder pressure on car 1 and car 50 during this test. This satisfies the loss of communication to a single CCD performance requirement.

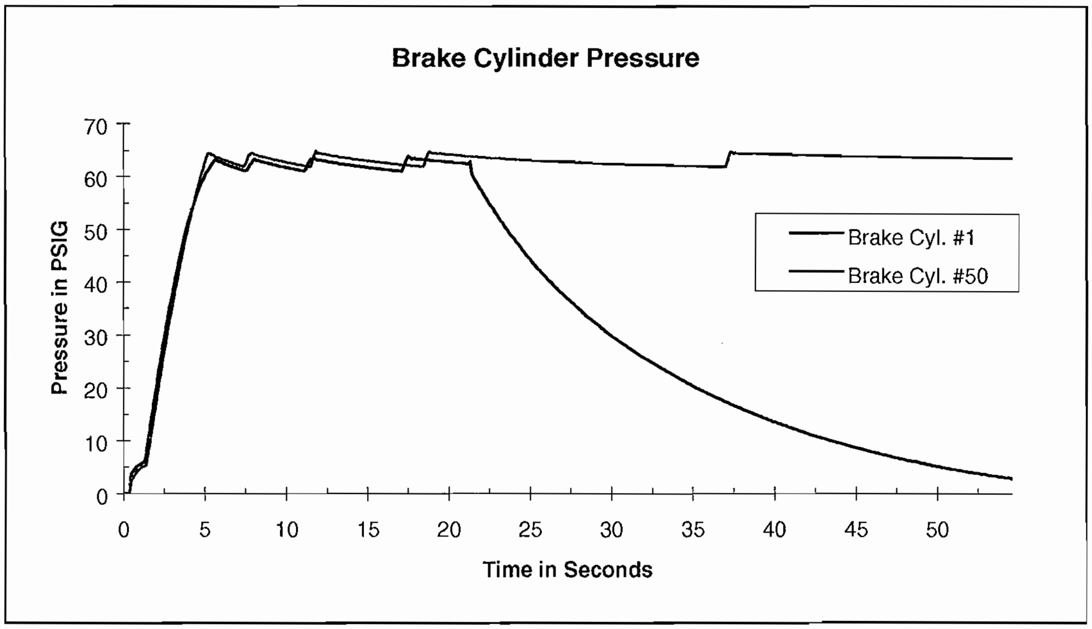

Figure 7. Brake Cylinder Pressure during Loss of Communication to a Single CCD Test

4.9 Loss of Trainline Power

The Loss of Trainline Power Test was performed in accordance with Section 5.4.4 of S-4200. The 230 Volt direct current system power was disconnected from the 50 car ECP brake rack. The HEU gave an audible warning and reported the loss of trainline power within 3 seconds.

Fifteen minutes after power was disconnected from the test rack, all CCDs were still functioning properly. Eight CCDs were cut out. The HEU reported that less than 85 percent of the brake units were operable and commanded a penalty emergency brake application. The system responded to a loss of trainline power in the manner specified in S-4200.

4.10 Brake Cylinder Leakage

The Brake Cylinder Leakage Test was performed in accordance to Section 5.4.5 of the May 1997 version of S-4200. The brake cylinder of car 1 was connected to the atmosphere. A minimum- service brake application was commanded. The CCD on car 1 reported low brake cylinder to the HEU and then cut out. S-4200 revision, May 1997, requires that the CCD stay cut-in when a brake cylinder under pressure condition occurs (the July 1998 revision calls for a CCD to cut out when a brake cylinder under-pressure condition exists in order to preserve reservoir pressure for potential emergency applications).

4.11 Excessive Brake Cylinder Pressure

The Excessive Brake Cylinder Test was performed in accordance to Section 5.4.6 of S-4200. A minimum-service brake application was commanded. Twenty seconds after the brakes applied, the brake cylinder of car 1 was connected to a 90 psig source via a 5/8-inch hose. Forty seconds after the high brake cylinder pressure occurred, the CCD on car 1 cut out and the HEU reported that the car 1 was cut out due to excessive brake cylinder pressure. S-4200 requires that the HEU report that the high brake cylinder pressure condition exists, but the CCD should not be cut out (the July, 1998 revision calls for a CCD to cut out when a brake cylinder over-pressure condition exists in order to preserve reservoir pressure for potential emergency applications).

Figure 8 shows the brake cylinder pressure for car 1 and car 50 during this test.

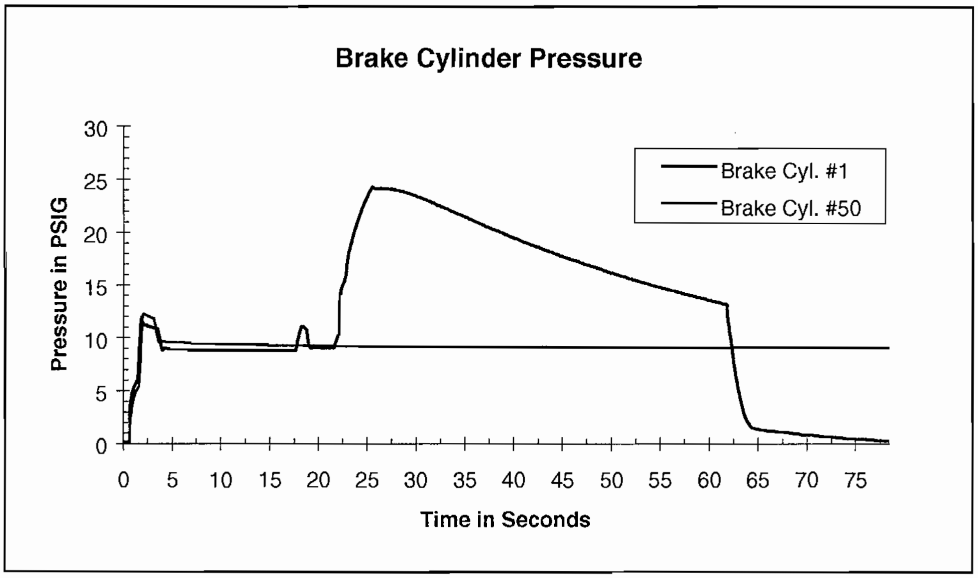

Figure 8. Brake Cylinder Pressure during the Cylinder over Pressure Test

4.12 <u>Less Than 85-Percent Operative</u>

The Less than 85-Percent Operative Units Test was performed in accordance with Section 5.4.8 of S-4200. CCDs were cut out one at a time by physically disconnecting them from the network. The HEU reported each disconnected CCD as inoperative. When eight CCDs were disconnected, the HEU reported that only 84 percent of the brake units were operative and commanded a penalty emergency brake application. This satisfies the performance requirements for a less than 85 -percent operable condition.

4.13 <u>Loss Of Brake Pipe Pressure</u>

The Loss of Brake Pipe Pressure Test was performed in accordance with Section 5.4.9 of S-4200. An angle cock between units 38 and 39 was closed and the brake pipe was opened after unit 50. The HEU provided a visual and audible warning for each CCD which reported a brake pipe pressure less than 50 psig. The HEU automatically commanded an emergency brake application after three CCDs reported a low brake pipe pressure. This satisfies the performance requirements for a loss of brake pipe pressure.

5.0 CONCLUSIONS

Upon completion of this set of tests, engineers determined that the TSM ECP brake equipment was suitable for installation on the FAST train. Table 1 provides a summary of the test results and, where a test criterion was not met, the safety impact. Although the TSM ECP brake equipment did not fully comply with the May 1997 version of S-4200, it does satisfy all the safety oriented requirements of this specification. TSM will be required to meet all provisions of the final specification when adopted by the AAR.

Table 1. 50 Unit ECP Brake Test Summary

Test Performed	S4200 Reference	Did or Did not meet Test Criterion	Comments
Minimum Service Requirements	Section 4.1	Met	
Full Service Requirements	Section 4.2	Met	
Electric Emergency Requirements	Section 4.3	Did not Meet	Units which have emergency and auxiliary reservoirs piped together reach target brake cylinder pressure 42% faster than normal. In this configuration, the system satisfies the emergency application requirements. **SAFETY IMPACT** – Minimal to none, since the emergency brake cylinder pressure build up still reaches full pressure faster than any conventional air brake system tested on the same rack configuration. The lag in emergency build up with this version of the TSM system only occurs when the emergency application closely follows a full service application, which is an uncommon operating scenario.
150 Car Charging Test	Section 5.1	Not Performed	Only 50 units installed on test rack.
Graduated Application and Release Requirements	Section 5.2	Met	
Repeated Full-Service Brake Applications	Section 5.3	Met	
System Loss of Communications	Section 5.4.1	Met	The front segment applied brakes 2 seconds after the rear segment. This behavior does not fully comply with S-4200, but was corrected in an updated software version.
Loss of Communications at Multiple Locations	Section 5.4.2	Met	
Loss of Communications to a Single CCD	Section 5.4.3	Met	
Loss of Train Line Power	Section 5.4.4	Met	
Brake Cylinder Leakage	Section 5.4.5	Did not Meet	CCD cut out after low cylinder pressure was detected. S-4200 requires that the CCD stay online. **SAFETY IMPACT** – none
Excessive Brake Cylinder Pressure	Section 5.4.6	Did not Meet	CCD cut out after high cylinder pressure was detected. S-4200 requires that the CCD stay online. **SAFETY IMPACT** – none
Intentional CCD Cut out	Section 5.4.7	Test Not Performed	HEU did not provide mechanism to intentionally cut out a specific CCD.
Less Than 85% Operative	Section 5.4.8	Met	
Loss of Brake Pipe Pressure	Section 5.4.9	Met	

APPENDIX

Specification S-4200
PERFORMANCE REQUIREMENT FOR TESTING ELECTRICALLY

CONTROLLED PNEUMATIC (ECP) CABLE-BASED

FREIGHT BRAKE SYSTEMS

Revised May 1997

NOTE: S-4200 is currently undergoing a Failure Modes, Effects and Criticality Analysis. A final version will be delivered to the Brake Systems Committee early 1999 for its consideration.

Specification S-4200

PERFORMANCE REQUIREMENT FOR TESTING ELECTRICALLY CONTROLLED PNEUMATIC CABLE-BASED (ECP) FREIGHT BRAKE SYSTEMS

Adopted: 1997

1.0 PURPOSE

The overall objectives of this specification are;

1. Assure that the performance of electrically controlled pneumatic (ECP) freight brake systems is uniform and consistent among equipment from different manufacturers.

2. Assure that cars equipped with AAR approved ECP brake systems from different manufacturers can be operated together in any electrically braked train.

3. Assure that AAR approved electric brake systems meet a high standard level of safety and reliability.

2.0 SCOPE

This specification defines the requirements for an AAR approved freight train power brake using electrically controlled freight brake systems suitable for service in all-electric braked train. Operation of such systems in a conventionally braked train is covered by AAR Specifications S-461, S-462, S-464 and S-467.

2.1 Definitions

2.1.1 Electrically Controlled Pneumatic (ECP) Brake System

A train power braking system operated by compressed air and controlled by electrical signals originated at the locomotive for service and emergency applications. The brake pipe is used to provide a constant supply of air to the reservoirs. Graduated release and re-application must be available. The system responds appropriately to undesired separation or malfunction of hoses, cabling, or brake pipe.

2.1.2 Car Control Device (CCD)

The CCD is an electronic control device which replaces the function of the pneumatic service and emergency portions during electric braking and provides for electrically controlled service and emergency brake applications. The CCD interprets and acknowledges the electrical signals and controls the reservoir charging, and the service and emergency braking functions on the car. It will also send a warning signal to the locomotive in case any of the components can not respond appropriately to a braking command. Each CCD has a unique electronic address that is keyed to car reporting marks and number.

2.1.2.1

In order to aid in system diagnostic services, the CCD will be able to measure the communication signal level at its interface to the communication media. The CCD will make this measurement with a resolution of ±0.05 Volts RMS. The signal measuring circuitry will have an impedance of no less than 20,000 Ohms in the frequency band of 100kHZ to 450kHz. The hardware which provides this measurement should have no adverse effect on the communication signal. It is recommended that this measurement be made on the low voltage side of the CCD coupling circuit.

2.1.3 Head End Unit (HEU)

Brake system control device used by the locomotive engineer to control the electric brake system. The specific functions of the HEU are;

- Provide man/machine interface to operate the ECP brake system, either directly or through a Locomotive System Integration (LSI) interface.

- Provide a data display to the engineer.

- Provide controls which allow the engineer to make the following brake commands with one movement;

  Minimum service (15% application)
  Full service (100% application)
  Emergency (120% application)
  Full release
  Graduate application and release in 1% increments

- Monitor the End of Train (EOT) beacon.

- Provide a means to turn off train line power whenever communications with the EOT is not established, and during operation in switching mode.

- Provide a means to supply a two second power application to "wake up" CCDs in a sleep mode.

- Provide mechanisms to conduct ECP brake system initial terminal test.

2.1.4 Overlay Brake System

An ECP brake system which is capable of operating in a conventionally braked train. A failure to the ECP brake system operating as an overlay system would enable a train to continue to operate as a pneumatically braked train when the ECP system is turned off. An electrically braked train must come to a complete stop before the ECP system can be turned off and train operation continued with the pneumatic brake. An overlay system and a pure ECP system must operate identically as specified below when operating in the electric mode.

2.1.5 Penalty Brake Application

An automatic electric emergency brake application made by the HEU when the locomotive engineer does not respond to a warning. A penalty brake application must remain in effect for 120 seconds and until the cause for the penalty application is eliminated and the brake command is 100%.

2.1.6 End Of Train Device (EOT)

The EOT will contain a means of communicating with the HEU, a brake pipe pressure transducer and a battery which will charge off the train line cable. The EOT will act as the last node in the train, and will transmit a status message once per second. The status message will consist of the current brake pipe pressure which will be displayed on the HEU. The EOT will not need an emergency brake pipe vent valve, so the hose to the EOT can be as small as but no smaller than 3/8" i.d. The EOT will also contain the electric train line termination circuit. The EOT must be connected to the network and must be transmitting status messages to the HEU before the train line power can be energized. The EOT must also have a flashing red warning light in accordance with FRA regulations.

2.1.7 Recovery from Intentional Non-Pneumatic emergency

An HEU emergency command must remain in effect for 120 seconds, after which the engineer must initiate a full service application.

3.0 PERFORMANCE SPECIFICATIONS

This section will describe the performance requirements for an ECP brake system. The electric brake system must function independently, and must not require the retention of the present service and emergency control valve portions. The brake system must include the following functions;

- Graduated brake applications and releases
- Continuous reservoir charging
- Pneumatic emergency back-up

3.1 ECP System Operation

The brake system is to operate as defined in the enclosed system flow charts and fault tree. The system flow chart describes the high level logic for the ECP system operation and identifies the major system functions and operational modes.

3.1.1 Train Brake Commands

The train brake commands (TBC) which determine the level of brake application for electrically controlled brake systems will be expressed as a percentage from 0 to 100% of the maximum full service braking force in 1% increments. The brake pipe pressure setting will determine the maximum full service brake cylinder pressure as shown in Table 1 and according to the following formula;

$$P_{BC} = 0.711 * P_s$$

These pressures are for cars loaded to 100% gross rail load.

3.1.1.1

Brake cylinder pressure tolerance will be ±2 psi. An initial command during the initialization of the train brake system will set each CCD to the full service brake cylinder pressure setting.

3.1.1.2

Emergency command will result in a brake cylinder pressure which is 120% of the full service brake cylinder pressure setting with a tolerance of ±2 psi (Table 1).

3.1.1.3

Minimum service application will be a 15% brake application. Once a minimum service application is made, it must be possible to reduce the brake application in 1% increments.

3.1.1.4

The HEU brake controller must provide the engineer a means for requesting;

a. Direct brake release
b. Graduated brake release
c. Graduated service brake application
d. Full service brake application
e. Emergency brake application

TABLE 1 - MAXIMUM FULL SERVICE BRAKE CYLINDER PRESSURES, LOADED BRAKE RATIOS AND EMERGENCY B.C. PRESSURES

Brake pipe	FULL SERVICE	MAXIMUM FULL SERVICE	EMERGENCY
80	56.9	11.38%	68.3
85	60.4	12.09%	72.5
90	64.0	12.80%	76.8
95	67.5	13.51%	81.0
100	71.1	14.22%	85.3

3.1.2 Brake Cylinder Pressure Control for Empty or Partial Load Conditions

3.1.2.1

The CCD must be designed such that the brake cylinder pressure for any application is reduced in proportion to the percentage of gross rail load. The percentage GRL for any car is determined by a message from the HEU during system initialization or by a load weighing device on the car. This percentage GRL is locked into the CCD memory every time the train brake system is initialized during the initial terminal air brake test or when the load condition of the train is changed. On those cars equipped with on-board load sensing equipment for conventional operation, the empty/load condition information from the HEU will take precedence when the car is operated in an electrically braked train. If the car is equipped with a proportional empty/load device, then the data from that device will take precedence over the information from the HEU.

When the brake system is initialized during the initial terminal inspection or at another location where the train is loaded or emptied, the car is told what its' percentage of gross rail load is, either by a message from the HEU or by an on-board self weighing device.

The CCD will provide the brake cylinder pressure necessary to keep the loaded and partially loaded car brake ratio no higher than 12.8% of gross rail load at a 90 psi brake pipe pressure under most load conditions. The loaded brake ratio will vary depending on the brake pipe pressure (see Table 1). The CCD will determine the brake cylinder pressure based on formulas and limits shown below. Note that the empty car brake ratio may be greater than 12.8%.

3.1.2.2 Full Service Brake Cylinder Pressure

The CCD can use the following procedure to compute the maximum brake cylinder pressure for its particular car loading. Note that this pressure will be less than or equal to the loaded brake cylinder pressure given in section 3.1.1, Train Brake Commands.

$$P_{BC\,MAX} = (NBR * W) / C$$

Where NBR = $0.128 * BPP / 90$

BPP = Operating brake pipe pressure

C = $(A_P * LR * EFF)$

A_P = Area of the B.C. piston(s)

LR = Lever ratio

EFF = Measured rigging efficiency @ 64.0 psi brake cylinder pressure

W = Total car weight at initial terminal

P_{BC} = Maximum brake cylinder pressure for the cars' current %GRL

The constant C is programmed into the CCD only once when it is installed on a particular car. The constant C remains unchanged as long as a particular CCD remains with its car. The CCD must have the software capability to be adjusted by the car builder for the constant C.

3.1.3 Pneumatic Emergency Back-up

Each CCD will provide the means to pneumatically (without requiring electrical power) apply emergency brake cylinder pressure if the brake pipe pressure falls below 40 psi. A pneumatically controlled brake pipe emergency vent valve will be optional on pure ECP cars, and required on cars equipped with overlay systems per AAR S-401, section 2.3. On operating CCDs, electric operation will take precedence over pneumatic operation, even if the brake pipe pressure falls below 40 psi. Once the brake pipe pressure exceeds 40 psi, or when the ECP system is operating, a means shall be provided to release emergency brake cylinder pressure.

3.1.4 Switching Mode

A means must be provided to allow operation of the ECP system when the EOT is not communicating with the HEU or when the train is separated during road switching operations. All modes of failure operation will be suspended when operating in switching mode with the exception of loss of communications and loss of brake pipe pressure. Loss of communications will be handled as outlined in 3.3.2.1.1 for cars cut off from HEU brake commands, but the HEU will ignore any lack of EOT status messages. Loss of brake pipe pressure will be handled as outlined in 3.3.2.2.5. Operation in switching mode cannot exceed 15 minutes and train speed cannot exceed 20 mph. If 20 mph is exceeded, a penalty electric emergency brake application must occur. If the 15 minute time period is exceeded, the engineer must be warned. If he does not reset the HEU for switching mode within 6 seconds, a penalty electric emergency brake application must occur. Switching mode must be selected prior to separating the train. Cars left standing without communication with the HEU will make an electric emergency application when three consecutive brake commands are missed. The electric emergency must be maintained on standing cars for at least one hour until communications with those cars and the HEU is reestablished.

NOTE: Brake pipe pressure must be vented to atmosphere on any standing cars. Then, if the CCDs time out after one hour and go into the sleep mode, the pneumatic emergency backup will keep the brake applied.

3.1.5 Automatic Brake Cylinder Venting

A means shall be provided to automatically vent brake cylinder pressure on an arriving train, either with the road locomotives before they are cut off from the train, or with a portable hand-held device. Head end power must not be required to accomplish this task. Use of switching mode prior to engaging automatic brake cylinder release will remove the need to use an EOT during this operation.

3.1.6 Inadvertent Use of the Pneumatic Brake

Whenever the ECP system is energized, and the ECP system is not in electric emergency, movement of the automatic brake valve handle to any position in the service application zone must result in an audible and visual warning to the engineer stating that the automatic brake valve handle was used in error. If the engineer does not respond to the warning within six seconds by returning the automatic brake valve handle back to release position, an ECP penalty emergency application must occur.

3.2 Messaging Requirements

3.2.1 Brake Commands

A train brake command (TBC) will be transmitted by the HEU once per second. The TBC will be a priority message. The TBC will be a percentage of full service braking force. 0% will be release, 15% will be minimum service, 100% will be full service and 120% will be emergency. Each TBC will include a status query for an individual CCD. Each CCD will be queried on a round robin basis until all CCD have been queried, then the process will repeat.

3.2.2 EOT Status Messages

The EOT will transmit a status message once per second. The status message will contain the brake pipe pressure which will be displayed on the HEU. The EOT message will be a priority message.

3.2.3 Individual Car Status Messages

Each CCD will respond to the appropriate status query by transmitting the brake pipe pressure, the brake cylinder pressure, the reservoir(s) pressure, the battery voltage, the CCDs cut-in/cut-out status, and other information as identified in the Intra-Train Communications Specification. This information will not be displayed on the HEU but will be stored in an event recorder. This will not be a priority message.

3.2.4 Exception Messages

A CCD will broadcast an exception message on the network for any of the following conditions:

- Improper brake cylinder pressure
- Failure of reservoir to charge
- Brake pipe pressure below 50 psi
- Reservoir pressure below 50 psi
- Loss of communications
- Low battery voltage just prior to taking itself off line

3.2.4.1

When a CCD experiences multiple faults, only the more serious fault will initially be reported and acted upon. Once the more severe fault is cleared then the lower priority faults will be acted upon. The hierarchy of fault severity is shown in Table 2.

3.2.4.2

When the HEU has commanded an emergency brake application, either penalty or intentional, a CCD must suppress all exception messages except loss of communications. Normal exception messages can resume only after the system has recovered from the emergency application as described in sections 2.1.5 and 2.1.7. Exception clear messages will be allowed when the HEU is commanding an emergency.

TABLE 2 - ECP BRAKE SYSTEM FAULT HIERARCHY

Fault Degree	General Fault Description	Examples
First Degree Fault (Most Severe)	CCD is unable to communicate with HEU. Independent action must be taken.	• Failure in network continuity. • CCD transceiver failure.
Second Degree Fault	A fault which affects the entire system occurs, but CCD is still in communication with HEU. The CCD will receive instructions from HEU.	Loss of brake pipe pressure.. Less than 85% operable bakes.
Third Degree Fault	A fault local to a CCD which requires the CCD to go offline occurs. If possible the CCD reports the fault to the HEU. The HEU will log the CCD as "inoperative."	Low CCD battery voltage. Etc.
Fourth Degree Fault	A fault local to a CCD which does not require the CCD to go offline occurs. The fault is reported to the HEU.	Low reservoir pressure. Low brake cylinder pressure. High brake cylinder pressure. Etc.

3.2.5 Control Messages

- CCD cut out
- Switching mode on or off
- Train initialization and serialization commands
- Yard train automatic brake cylinder release

(Other messages concerning car health monitoring and distributed locomotive control are covered in the Intra-Train Communications Specification.)

3.3 System Operation

3.3.1 Initial Terminal Test

Note that the following describes the requirements for the initial terminal brake system test, and is treated separately from any required safety appliance or running gear inspections.

3.3.1.1 Train Make Up Procedures

The EOT must be connected to the last car, and all cables must be connected completing a circuit, before train line power can be energized.

3.3.1.2

The remaining test procedures are shown in the attached Terminal Test flow chart.

3.3.2 Failure Modes

These failure modes are for pure ECP or overlay operation.

3.3.2.1 Signal Transmission Failure

Signal transmission failure is defined as a total failure of the entire electric brake control network, such that communication to and/or from the last car is broken at some point in the train.

3.3.2.1.1 Single or Multiple Breaks in the Communications Network

If any CCD determines that it has missed three consecutive HEU beacons, it will maintain the current brake application and transmit a "loss of signal" message. If that CCD subsequently receives a "loss of signal" message from any other CCD within one second, then that CCD will assume that the entire communications link is broken and must make an electric emergency brake application. If that CCD does not receive a "loss of signal" message from any other CCD, it will cut itself out with the brake cylinder connected to atmosphere per Para. 3.3.2.2.2. The HEU must detect the failure when three consecutive EOT status messages are missed. The HEU must then transmit an electric emergency brake application command to all CCDs still in communication with the HEU.

3.3.2.1.2

The locomotive engineer must be given an audible and visible warning of network failure, and an electric emergency application must be made. Emergency application on the cut off cars must be held for one hour, after which the pneumatic emergency will maintain the application as the CCDs time out and enter a "battery conservation" mode.

3.3.2.1.3

In the event of train line communications failure, the system will return to normal operation when the HEU receives three consecutive EOT messages after the train has come to a stop per Para. 2.1.5.

3.3.2.2 Individual Car Control Device Failure

Individual car control device failure is defined as the failure of any one CCD to respond appropriately to commands from the HEU.

3.3.2.2.1 Incorrect Brake Cylinder Pressure

If the brake cylinder pressure monitored by each CCD does not correspond correctly ($\pm$5 psi) with the brake signal command after allowing for the build up time or release time, a 15 second settling period and after correcting for any empty or partially loaded brake cylinder pressure, the locomotive engineer must be given a warning of the failure, and must be informed of the location in the train of the defect. The locomotive engineer must have the option of allowing the defective brake system on that car to continue to operate.

3.3.2.2.2 Local Signal Failure

If the signal to an individual CCD should fail for any reason, that CCD would not receive any brake commands. When three consecutive brake commands have been missed, that CCD would attempt to broadcast a "loss of signal" message, but would be unable to do so. After the fifth brake command has been missed, that CCD would "go to sleep" with the brake cylinder connected to atmosphere. The locomotive engineer must be given a warning that communication with that CCD has failed when the status message from the HEU to that CCD is not answered (see Para. 3.2.1 and 3.2.3), and must be informed of the location in the train of the defective CCD. If at a later time the CCD begins receiving the HEU beacons and has no other faults, it will cut itself in and continue to operate normally. The HEU will inform the engineer that the CCD is back on line if it receives a response from that CCD during a normal polling message.

NOTE: If the failure occurs on a car equipped with an overlay system, that car may have to be cut out pneumatically in order to prevent stuck brakes. Stuck brakes can occur when the pneumatic system on an overlay car reacts to small pressure changes in the brake pipe when the rest of the train is operating in ECP mode.

3.3.2.2.3 Local Transceiver Failure

Communication within the entire network may be disrupted if the transceiver in an individual CCD, or any other ECP brake system component, fails to a noise generating mode. A means must be provided to detect and disable a noise generating transceiver within two (2) seconds of the initial occurrence of the failure.

3.3.2.2.4 Loss of More Than 15% of CCDs in Train

If communication to more than 15% of the CCDs in any train fails for any reason, or if more than 15% of the CCDs are cut out by the locomotive engineer, the locomotive engineer will be given an audible and visual warning. The locomotive engineer must then take action to apply the brakes or increase a current brake application in order to reduce the speed of the train. If the locomotive engineer takes no such action after a 6 second period, a penalty emergency brake application must occur.

3.3.2.2.5 Brake Pipe Blockage

If the brake pipe becomes blocked, restricted, or an angle cock is closed, the locomotive engineer must be given an audible and visual warning that the reservoirs behind the blockage are not being charged. The locomotive engineer will be warned of a possible failure and the location in the train of the reservoir nearest to the locomotive which triggered the warning. A penalty emergency brake application must result if the reservoir pressure on three or more CCDs falls below 50 psi in ten seconds or less.

3.3.2.2.6 Brake Pipe Separation

If the brake pipe breaks or separates, each CCD must transmit a "loss of pressure" message to the HEU when the brake pipe pressure is at or below 50 psi. When the HEU receives three consecutive "loss of pressure" messages from at least three separate cars within ten seconds, HEU transmits a penalty electric emergency brake application command. NOTE: In the case of a train break-in-two, the train may also be initiating an electric emergency brake application due to signal loss (see para.3.3.2.1.1).

3.3.3 Recovery from Emergencies

In all cases, an ECP emergency has to stay in effect for 120 seconds. Recovery cannot be made until the 120 second time period has elapsed.

CAUSE	RECOVERY PROCEDURE
Low B.P. pressure (3.3.2.2.6)	After the 120 second time period, any three CCDs reporting B.P. pressure of 60 psi or higher will start a 60 second timer. After 60 seconds, the engineer may command a full service application. If the B.P. pressure is at least 60 psi at all reporting CCDs, then the system returns to normal operation. If there are still at least three CCDs in the train reporting lower than 50 psi B.P. pressure, these CCDs will again initiate an emergency application. The engineer will then have to wait 120 seconds and repeat the recovery process. If the recovery is still unsuccessful, a serious leak still exists in the train. This recovery procedure is identical in either switch or run mode.
Loss of communications (3.3.2.1)	After the 120 second waiting period, and after the break in the communications line has been repaired, the system will return to normal operation when the HEU receives the EOT beacon. At that point a full service application will restore the system to normal operation. If the communications break cannot be repaired, and the train must be moved in switch mode to a siding, the CCDs behind the communications break which are in emergency will release when the brake pipe pressure is reduced by 15 to 35 psi and held for 30 seconds.

Inadvertent use of the pneumatic brake	After the 120 second waiting period, a full service brake application will return the system to normal operation.
Percentage of operative brakes falls below 85%	After the 120 second waiting period, the train may be operated in switch mode to set out enough defective cars to return to at least 85% operative brakes. The system must be re-initialized to return to normal operation.
Switching mode time or speed exceeded	After the 120 second waiting period, reset the system to switch mode.

4.0 PERFORMANCE TESTS FOR SINGLE CAR BRAKE EQUIPMENT

These tests will be made on an AAR approved single car test rack. Initialize the CCD as follows;

C	=	572	BPP	=	90 psi
GRL	=	286,000 lbs	Lt. Wt	.=	43,000 lbs

This will result in the following target brake cylinder pressures for different load conditions as shown in table 3;

TABLE 3 - TARGET BRAKE CYLINDER PRESSURES

% TBC	100% LOAD	50% LOAD	EMPTY
0	0	0	0
10	6.4	6.4	6.4
15	9.6	9.6	9.6
20	12.8	11.2	10.2
30	19.2	14.4	11.4
40	25.6	17.6	12.7
50	32.0	20.8	13.9
60	38.4	24.0	15.1
70	44.8	27.2	16.3
80	51.2	30.4	17.6
90	57.6	33.6	8.8
100	64.0	36.8	20.0
120	76.8	44.2	24.0

The following tests 4.1 through 4.4.1 are to be conducted at 100% load, then repeated at 50% load and 0% load.

4.1 Minimum Service Requirements

4.1.1 Application Test

Make a minimum service electric brake application (15% brake application). Final brake cylinder pressure should be 9.6 ± 2 psi in no more than 2.0 seconds

4.1.2 Release Test

Release from a minimum service application. Brake cylinder piston must fully retract into the cylinder.

4.2 Full Service Requirements

4.2.1 Application Test

Make an electric full service brake application (100% brake application). Brake cylinder pressure must build up to the pressure listed in Table 3 ±2psi in no more than ten seconds.

4.2.2 Release Test

Release the electric full service brake application. Brake cylinder pressure must reduce from full service brake cylinder pressure to 5 psi or less in no more than 15.0 seconds.

4.2.3 Graduated Release Test - Application

With the auxiliary reservoir fully charged, make an electric full service brake application (100% brake command) and hold for 10 seconds.

4.2.4 Partial release Test

Make a partial release to a 40% brake command. Brake cylinder pressure is to be in accordance with Table 3 ±2psi. Hold for one minute.

4.2.5 Application After Partial Release Test

Make an electric full service application (100% brake command) and hold for 10 seconds. Brake cylinder pressure must be in accordance with Table 3 ±2psi. At the completion of this test, fully release the brake application.

4.3 Electric Emergency Requirements

4.3.1 Emergency Application Test

Immediately after the brake release in Para. 4.2.5, make an electric emergency application (120% brake application). Emergency brake cylinder pressure build-up time from 0 psi to pressure listed in Table 3 ±2psi will be no more than 10 seconds.

4.4 Graduated Application and Release Requirements

4.4.1 Graduated Application and Release test

Make a minimum service application (15% brake command). Reduce the brake command to 10%, then make brake applications in increments as shown in Table 3 up to a full service application, then release the brakes by the same increments. Wait five seconds between each application and release. Brake cylinder pressure at all brake commands must correspond to the limits listed in Table 3 with a tolerance of ±2 psi.

5.0 PERFORMANCE TESTS ON 150-CAR TEST RACK OR TRAIN

These tests will be made on an AAR approved 150 car test rack or an equivalent train. The test rack or test train shall consist of at least 150 operative brakes with a minimum of 50 feet of brake pipe per brake for a minimum total of 7,500 feet of brake pipe. Brake cylinder piston travels must be at the maximum allowable limits. All CCDs will be initialized as follows;

C	=	572
BPP	=	90 psi
GRL	=	286,000 lbs
Lt. Wt.	=	43,000 lbs

The following tests are to be conducted at 100% load.

NOTE: A dummy speed signal will have to be provided in order to recover from any electric emergency or penalty applications resulting from the following tests. Penalty electric emergency applications must be held until the train speed is zero. The speed signal will also be necessary when testing in switching mode.

5.1 Charging Test

5.1.1

Start test with all reservoirs drained to atmospheric pressure. With the brake pipe feed valve set at 90 psi, charge the brake pipe. Main reservoir must never fall below 110 psi during this test.

5.1.2

The reservoirs on the last car must be pressurized to 90 psi in no more than 55 minutes.

5.2 Graduated Application and Release Requirements

5.2.1

Fully charge the brake system until the reservoirs on the 150th car are pressurized to at least 85 psi.

5.2.2

Make a minimum service application (15% brake command). Reduce the brake command to 10%, then make brake applications in increments as shown in Table 3 up to a full service application, then release the brakes by the same increments. Wait five seconds between each application and release. Brake cylinder pressure at all brake commands must correspond to the limits listed in Table 3 with a tolerance of ±2 psi.

5.3 Repeated Full Service Brake Applications

5.3.1

With the brake system on the last car charged to at least 85 psi, make a full service brake application. When the brake cylinder pressure of the first car reaches 64.0±2psi, record the brake cylinder pressure on the last car, then fully release the brake.

5.3.2

When the brake cylinder pressure begins to release on the last car, wait fifteen seconds, then make a full service brake application. The brake cylinder pressure on the last car must match the brake cylinder pressure recorded previously within ±2 psi after waiting 15 seconds.

5.4 Failure Mode Tests

These tests will be made under the test conditions described in Section 4.0 (150-car rack tests or equivalent train).

5.4.1 System Loss of Communications

Disconnect the signal (but not the power if cable powered) from the train. The system must give an audible and visible warning of total control network failure. An electric emergency brake application must be initiated simultaneously on all cars in not more than four seconds from the time of signal disconnection. Wait for at least 1 hour. The brakes on the disconnected CCDs must remain applied for at least 1 hour, and then they must go into a battery conservation mode within the following five minutes. At the conclusion of this test, reinitialize the system.

NOTE The release is intended to verify that a car set out at a siding will enter the "battery conservation or sleep" mode within the time specified in order to save the battery. If the brake pipe pressure was less than 40 psi, the brake would be maintained by the pneumatic emergency feature.

5.4.1.1

Repeat the test in 5.4.1, but open the brake pipe to atmosphere after the brakes apply due to communications loss. When the disconnected CCDs time out after the 1 hour waiting period, the brakes must remain applied with the pneumatic emergency back up. At the conclusion of this test, recharge the brake pipe and reinitialize the system.

5.4.2 Loss of Communications at Multiple Locations

Reconnect the signal, recharge the reservoirs to at least 85 psi, then simultaneously break the signal between cars 50 and 51, and between cars 100 and 101. All three sections must make a simultaneous emergency brake application within 4 seconds of the communications break. Reconnect the signal so that communications with the EOT is regained. After the emergency has been in effect for one minute, make a full service application. The HEU must not respond, and the emergency must stay in effect. After the emergency application has been in effect for at two minutes, make a full service brake application. The system must then return to normal operation.

5.4.3 Loss of Communications to a Single CCD

Make a 100% (full service) brake application and wait for at least 8 seconds. Break the communications path to the CCD on one of the cars. The brakes on that car must begin to release within six seconds.

5.4.4 Loss of Train line Power

Reconnect the signal, release and recharge the brake system, and disconnect the power, but not the signal, from the cable. The system must give an audible and visible warning of total power failure. The system must continue to operate on battery power for at least 15 minutes. Cut out 16 CCDs (10.7%). The HEU must command a penalty emergency brake application. After waiting 2 minutes, re-connect the cut out CCDs.

5.4.5 Brake Cylinder Leakage

Reconnect the power, then disable any one CCD in the consist by opening a brake cylinder pipe to atmosphere. Make a 15% brake application. After a 15 second waiting period, the system must give the engineer a warning of the low brake cylinder pressure, indicate the brake cylinder pressure and indicate the location in the train of the defect. Close the brake cylinder pipe opening and release the brake.

5.4.6 Excessive Brake Cylinder Pressure

5.4.6.1

Make a 15% minimum service brake application. With the 15% brake command in effect, connect brake pipe pressure, reservoir pressure or some other higher air pressure source to brake cylinder pressure on any one CCD. After a 15 second waiting period, the system must give the engineer a warning of the high brake cylinder pressure, indicate the brake cylinder pressure and indicate the location in the train of the defect. The CCD controlling that brake cylinder **must not** release the brake. Remove the high pressure air source at the completion of this test..

5.4.7 Intentional CCD Cut Out

With the 15% brake command still in effect, send a command from the HEU which will electrically cut out an individual CCD. The brake cylinder pressure on the that CCD must reduce to atmospheric pressure. Make a full service brake application. The cut out CCD must not respond.

5.4.8.1 Less Than 85% operative

Release the brake. Send a command from the HEU to cut out another 21 CCDs spaced at random throughout the train to simulate a number of defective or intentionally cut out CCDs (this assumes that the CCD cut out in 5.4.7 is already cut out. The total number of CCDs needed to be cut out for this test is 22) The HEU should give an indication that 14.7% of the CCDs have been cut-out.

5.4.8.2

Cut out one more random CCD, which increases the total number of cut out CCDs to 23 (15.3%). The system must give an audible and visual warning in not more than two seconds that more than 15% of the CCDs are inoperative. Six seconds after the warning a penalty electric emergency brake application must occur. At the completion of the test cut in all CCDs and release the brake.

5.4.9 Loss of Reservoir Charging

With all reservoirs fully charged, and all CCDs cut in, close the angle cock at a random location in the train. Make a 15% brake application and hold until all brake cylinder pressures have stabilized. The system must give an audible and visual warning that the first reservoir behind the closed angle cock is not charging.

5.4.10 Loss of Brake Pipe Pressure

Close the angle cock between cars 100 and 101 and partially open the angle cock at the rear of the train so that the brake pipe pressure is reduced at a service rate. A pneumatic emergency must not occur. The locomotive engineer must be given an audible and visual warning of loss of brake pipe pressure when the pressure on any three CCDs falls below 50 psi, and an electric emergency application must be initiated on all cars within two seconds of the warning.

5.4.10.1 Recovery from Emergency due to Loss of Brake Pipe Pressure

Recover from the penalty application is described in section 3.3.3.

5.4.11.1 Switching Mode

With the last car charged to at least 85 psi, make a full service (100% brake command) application. Switch the system over to switching mode. Close the angle cock and disconnect the signal between cars 50 and 51. The brakes on cars 51 through 150 must apply in emergency, while the brakes on cars 1 through 50 remain at full service. Release the brakes. After a fifteen minute time period, the HEU must give a warning that the switching mode time has expired. Do not reset the HEU for switching mode. The HEU must make a penalty electric emergency application on the first 50 cars within six seconds of the warning. Continue waiting for a total of 1 hour. The brakes on the last 100 cars must remain applied in emergency. The brakes on the first 50 cars must remain applied in emergency. After the expiration of the 1 hour waiting period, the brakes on the last 100 cars must release. Open the brake pipe on the last car to atmosphere. The brakes must reapply on each car when the brake pipe pressure at that car is reduced to 40 psi or less.

5.4.11.2

Repeat 5.4.11.1, but when the HEU warns of switching mode time-out, reset the HEU for switching mode. The brakes must stay released on the first 50 cars, and remain applied on the last 100 cars.

5.4.11.3

Repeat the test conditions in 5.4.11.1, but after the simulated train separation is made and the first 50 cars have released their brakes, increase the dummy speed signal to simulate 21 mph. The first 50 cars must immediately apply a penalty electric emergency brake application.

6.0 GENERAL REQUIREMENTS FOR ELECTRIC BRAKE INSTALLATIONS ON INDIVIDUAL CARS

6.1 Manual Brake Cylinder and Reservoir Venting

A method to manually vent brake cylinder pressure and reservoir pressure must be available at every CCD location from both sides of the car. The method of brake cylinder pressure venting must require no more than three seconds per car. It must be possible to vent the brake cylinder pressure independently of the reservoir pressure.

7.0 ENVIRONMENTAL TESTS

7.1 Vibration and Shock Environment

The CCD shall be designed and mounted on the base structure of the car to withstand continuous vibrations, in the three major axes, of 0.4 g RMS with a frequency content from 1 Hz to 150 Hz, containing peak values of ± 3 g in the 1 Hz to 100 Hz bandwidth. The CCD and its mounting shall also be designed to withstand a longitudinally oriented shock impulse (half sine wave) of 10 g peak with a ramp time of 20 msec to 50 msec. If the CCD is mounted on the car strength members (ribs, slope sheet support columns, etc), then the bracket and mounting arrangements, together with the electronics packaging, shall be designed to provide protection from the amplification effects of any local vibration resonances. It should be noted that peak resonant acceleration levels in excess of 15 g in the 100-150 Hz range and values in excess of 50 g in the 200-500 Hz range have been measured on car strength members as a result of shock impulses sustained during yard impacts.

7.2 Temperature and Humidity tests

7.2.1

Mount the CCD on an AAR approved single car test rack or an approved equivalent. Use an outside air source at ambient temperature to charge the brake system. Place the test rack and a suitable air source in an environmental chamber. Do not use air driers. Soak the equipment at -50±2°F for 24 hours

7.2.2

After the equipment has soaked at -50±2°F, repeat the tests described in Para. 4.4.1. The CCD must meet all of the requirements outlined in Para. 4.4.1.

7.2.3

Repeat test described in Para. 7.2.1 and 7.2.2 at temperature of 150±2°F.

8.0 APPROVAL PROCEDURE

8.1

The manufacturer will apply in writing to the Director, Technical Committees-Quality Assurance, Mechanical Division, Association of American Railroads, 50 F Street NW, Washington, DC, 20001, to initiate the approval process. This application for approval will include a description of the product and its intended use.

8.2

It is the manufacturers obligation to establish that the ECP equipment will comply with, and satisfactorily function, per this performance specification, and to the Intra-Train Communications Specification as witnessed by representatives of the AAR.

8.3

If the ECP equipment being offered is designed to emulate the performance of conventional pneumatic control valves in conventional trains, the ECP equipment must also pass the following AAR specifications.

8.3.1

"Performance Specifications For Single Capacity Freight Brakes." AAR Standard S-461.

8.3.3

"Performance Testing Procedure For Freight Brakes On A 150-car Test Rack." AAR Standard S-464.

8.3.5

"Performance Testing Procedure For Control Valve Applied to Single Car Rack." AAR Standard S-466.

8.4

The testing as described in this specification and the testing for "emulator" ECP equipment as outlined in Para. 8.3 must be performed on AAR certified test racks certified according to the following.

8.4.1

"Specifications For Freight Brake 150-car Test Rack." AAR Standard S-463.

8.4.2

"Specification For Freight Brake Single Car Test Rack." AAR Standard S-465.

8.5

ECP brake components for single car tests must be selected from a production lot of not less than 50 car sets of equipment. ECP components for 150-car rack testing must be selected from a production lot of not less than 200 car sets of equipment. All test samples will be selected by an AAR representative.

8.6

Results of all required tests will be provided by the manufacturer and furnished free of charge to the AAR for evaluation.

8.7

After the AAR examination of the ECP brake equipment and supporting information, the AAR will notify the manufacturer or supplier as to whether the product has been given a conditional approval or has been disapproved.