



APTA PR-M-S-021-17

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PRESS Mechanical Working Group

Electronically Controlled Pneumatic Cable-Based Braking System — Performance Requirements for Passenger Applications

Abstract: This standard contains the minimum performance requirements for electronically controlled pneumatic (ECP) brake systems operating on passenger cars that are part of the general railroad system. This standard augments the AAR Standard S-4200 specification for ECP braking equipment to capture shared requirements specific to U.S. passenger transit applications.

Keywords: brake, ECP, railcar, train

Summary: This document identifies the minimum performance requirements for the operation of ECP brake systems in service on passenger train equipment. ECP brakes offer advantages to the operation of passenger trains over older pneumatic-controlled brake systems. ECP brake systems improve operational braking performance, improve maintenance monitoring functions and reduce train stopping distance. This standard addresses functional performance measures for each operating mode of an ECP brake system, establishes interoperability between freight and passenger systems, and defines fault response and recovery functions. This standard is to be used together with APTA PR-M-S-020-16, “Electronically Controlled Pneumatic (ECP) 26C Emulation Braking System — Performance Requirements for Passenger Applications.”

Scope and purpose: This document identifies differences in functionality between passenger transit ECP applications and AAR Standard S-4200 freight applications, retaining elements of AAR Standard S-4200 applicable to passenger trains and adding new requirements specific to passenger trains. This standard ensures that APTA-approved ECP brake systems from different manufacturers are interoperable and that they meet a high level of safety and reliability. The objectives of this standard are to define functional requirements specific to U.S. trains operating in passenger service equipped with ECP; to ensure that trains equipped with APTA-approved ECP brake systems are interoperable and function consistently and uniformly; and to ensure that APTA-approved electronic brake systems meet a high standard for safety and reliability.

This document represents a common viewpoint of those parties concerned with its provisions, namely operating/planning agencies, manufacturers, consultants, engineers and general interest groups. The application of any standards, recommended practices or guidelines contained herein is voluntary. In some cases, federal and/or state regulations govern portions of a transit system's operations. In those cases, the government regulations take precedence over this standard. The North American Transit Service Association and its parent organization APTA recognize that for certain applications, the standards or practices, as implemented by individual agencies, may be either more or less restrictive than those given in this document.

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Introduction

APTA recommends the use of this document by:

- individuals or organizations that operate rail transit systems;
- individuals or organizations that contract with others for the operation of rail transit systems; and
- individuals or organizations that influence how rail transit systems are operated (including but not limited to consultants, designers and contractors).

Electronically Controlled Pneumatic Cable-Based Braking System — Performance Requirements for Passenger Applications

1. Description of ECP braking system for passenger applications

An ECP brake system is a train-powered braking system actuated by compressed air and controlled by electronic signals originating from a lead locomotive or cab car. The electronic signals are used to communicate service and emergency brake applications, as well as control power and receive feedback from other devices in the train. Since brake commands are derived from electronic signals, the brake pipe will typically remain charged and provide backup brake commands.

The “cable-based” ECP brake system provides communications and a potential source of power to all the ECP brake devices in the train via a two-conductor electric trainline that spans the entire length of the train.

The system provides shorter response times to braking commands and includes support for graduated releases and reapplications. The system responds appropriately to undesired separation or malfunction of hoses, cabling or brake pipe.

2. Functional and performance specification

This section describes the functional and performance requirements for an ECP brake system (which shall be designed for a minimum of 180 network devices spanning 12,000 ft), both in normal operation and in response to faults. The environmental conditions under which the system must operate are described in Section 3.0.

2.1 Primary functions

The brake system shall provide the following primary functions:

- Graduated brake applications and releases
- Continuous reservoir charging
- Adjustment of braking levels to car loading
- Continuous fault detection and equipment status monitoring
- Pneumatic backup
- passenger ECP operating mode
- passenger graduated and direct release emulation mode
- passenger ECP end-of-train (EOT) functionality

The system must also provision for the following:

- interoperable snow braking control

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- local load-weigh functionality

Section 2 is divided into five major areas, this first area (section 2.1) is a list of Primary Functions. The second area, (Section 2.2), covers system modes of operation, including pneumatic backup. The third area (Section 2.3) describes all normal operational functions performed by the system. The fourth area (Section 2.4) describes all the fault response functions of the system. The fifth area (Section 2.5) describes the functional features for mitigating cross communications between two trains. The latter three areas describe in detail the functions and required performance of all major components and subsystems of the ECP brake system.

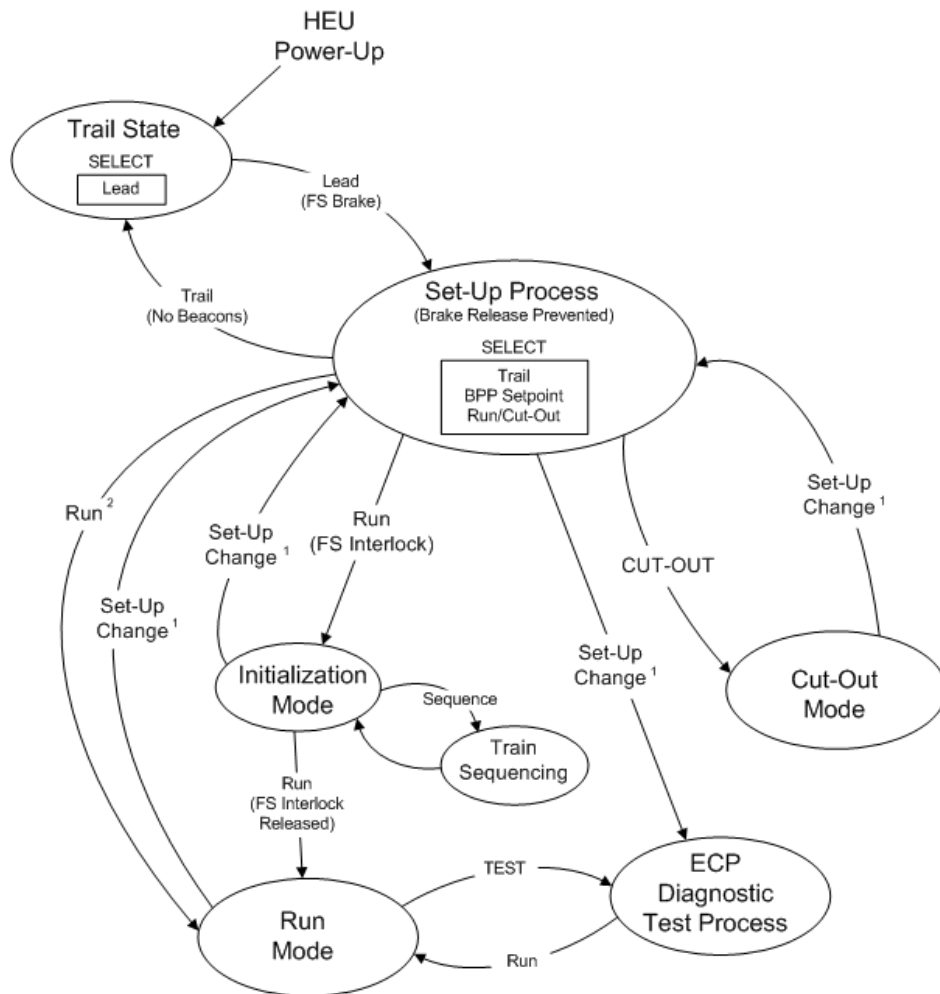
2.2 Operating modes

The passenger ECP system shall be defined by a passenger ECP mode of operation that is distinct from the freight mode of operation. When in passenger mode, several operating modes are defined, as illustrated in **Figure 2.1**. A particular set of procedures is followed and functions are performed in each mode. Three modes of operation are covered in this Section: initialization mode (Section 2.2.3), RUN mode (Section 2.2.5), and CUTOFF mode (Section 2.2.6). An additional Section, 2.2.7 “All Modes,” lists procedures and functional references that apply to all ECP brake system operating modes. Also described in this area are the power-up Head End Unit (HEU) lead/trail selection procedure (Section 2.2.1), setup operations (Section 2.2.2), and ECP brake system diagnostic tests (Section 2.2.4).

The HEU shall broadcast the current operating mode to all Control Devices (CCDs) as part of the HEU beacon.

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FIGURE 2.1
 Passenger ECP System Operating Modes



NOTES:
 1. SET-UP CHANGES ARE ALLOWED ONLY IF THE TRAIN IS STOPPED OR A FULL-SERVICE BRAKE APPLICATION HAS BEEN IN EFFECT FOR AT LEAST 120 SECONDS.
 2. TRANSITION TO RUN MODE WITHOUT INITIALIZATION IS ALLOWED ONLY IF THE EOT BEACON HAS NOT BEEN LOST FOR MORE THAN 15 SECONDS SINCE THE PREVIOUS COMPLETION OF INITIALIZATION

2.2.1 Head end unit lead/trail selection

2.2.1.1 Description of HEU Trail

The HEU, when powered up, shall default to trail state. When in trail state, the HEU shall not broadcast any HEU beacons or system commands.

2.2.1.2 Selection of HEU Lead

2.2.1.2.1 The engineer must select the HEU at the locomotive or cab car designated as “lead”; if any other HEU connected to the network has already been selected as lead, this HEU shall not assume lead state until all other HEUs have been placed in trail state or trainline power is off and the engineer expressly confirms Lead operation should be allowed. Multiple lead HEUs in the network shall be handled as described in Section 2.4.11.

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2.2.1.2.2 After lead selections are made and prior to completing the setup process, the lead HEU broadcasts HEU beacon messages containing a full-service (100%) TBC, a train line power off command, and initialization mode. Then the HEU continues the setup process.

2.2.2 Setup

Prior to entering passenger ECP operating mode, the system may require the operator to select the passenger lead cut-in mode of operation.

2.2.2.1 Description of Setup

Setup is an operation that allows the engineer to change the ECP brake system configuration. With the exception of changing the train line power mode, setup changes shall not occur unless the train is stopped or until a full-service application has been in effect for 120 seconds. Any setup change shall require an operator confirmation to become effective.

2.2.2.1.1 Entering Setup from Trail State

Upon entering Setup from Trail state, all ECP brake system configuration information and operating mode may be selected. Setup shall not be exited until all configuration information is confirmed or the HEU is placed in the Trail state.

2.2.2.1.2 Entering Setup from RUN, Initialization, CUTOFF Mode, or Diagnostic Tests

Upon entering Setup from an operating mode, some or all ECP brake system configuration information and operating modes may be changed.

2.2.2.2 Setup operational procedures

In Setup, the following information may be entered.

2.2.2.2.1 HEU Trail

If Trail state is selected, then no other information needs to be entered. The HEU enters Trail state.

2.2.2.2.2 Train Line Power Mode Selection

The engineer may select Automatic Power mode or Power Off mode at any time (see Section 2.3.3). The default is Power OFF.

2.2.2.2.3 Brake Pipe Pressure Setpoint

The engineer must select the BP pressure setpoint (BPP setpoint), or the engineer may accept the default setting. The BP pressure setpoint establishes the ECP brake system reference BP pressure. The minimum pressure setting for ECP brake systems shall be 70 psig and the maximum pressure setting shall be 110 psig, in increments of 1 psi.

2.2.2.2.4 Empty/Load

Car loading is determined locally at the car or cab car (see Section 2.3.8, “CCDs determine car load value”).

2.2.2.2.5 Operating Mode Selection

The desired operating mode (RUN or CUTOFF) may be entered. If CUTOFF mode is selected, then the HEU shall release the brake application interlock and enter the desired mode. Transition to RUN mode without initialization is allowed only if the EOT beacon has not been lost for more than 15 seconds since the previous completion of initialization.

2.2.3 ECP brake system initialization (INIT mode)

After the operator has selected a lead locomotive or cab car and selected the required setup parameters, the system shall perform an initialization process per the requirements defined in this section. If ECP is already initialized, then the ECP system shall also allow the operator to reinitialize the system per the requirements defined in this section.

The ECP brake system must be initialized prior to entering RUN mode so that network devices and train conditions are registered. An EOT device is required to be connected for normal initialization of the train. When Initialization mode is entered, a full-service interlock is applied. The initialization sequence shall be performed by the HEU when RUN mode is selected by the engineer. Initialization involves establishing or confirming identity and position of all network devices in the train line communication network. It also involves assigning a network address to each network device and downloading operational data, including vehicle weight and brake pipe pressure setpoint (see AAR Standard S-4230, latest revision). Specifically, the initialization procedure shall include the following:

1. Initial power-up to restart and cut in CCDs and EOT. In order to initialize the ECP system, CCDs and EOT shall be restarted via a train line power application. The HEU shall prompt the engineer when entering Initialization to set train line power to AUTO when safe to do so. Within 2 seconds after the train line voltage has reached 100 Vdc at the device, any CCDs or EOT that were shut down restart (wake up) and begin to cut in. This procedure is necessary to prepare CCDs and EOT for ECP brake system initialization. This 2-second power-up function shall not depend on the existence of EOT or HEU beacons on the network. When the EOT is activated, it shall begin transmitting EOT beacon and status messages to the HEU. The EOT shall be activated by the presence of train line power.
2. The HEU shall establish the version compatibility level of the train per AAR Standard S-4230, latest revision.
3. The HEU shall poll the network to identify all network devices. When devices have been identified, they shall be assigned network addresses and shall be added to the HEU database.
4. The HEU database shall indicate the relative position of each network device within the train (correlated to reporting marks or road numbers). The relative position shall be determined as defined in Section 2.2.3.1
5. If additional CCDs are added to the database, the HEU shall configure the cars by down-loading operational data to each additional CCD.
6. Car-specific data from the car ID module shall be retrieved from each CCD.
7. The HEU transmits train configuration data to all ECP train line devices. This information includes the train net braking ratio and brake pipe pressure setpoint.
8. Each CCD determines its car loading value in order to adjust brake cylinder pressures to car loading (see Section 2.3.8, “CCDs Determine Car Load Value.”)
9. Locomotive-specific data from the locomotive ID module shall be retrieved from each trail HEU.
10. The HEU shall prompt the engineer to confirm or enter the total number of potentially operative brakes. When prompted to enter the total number of potentially operative brakes, the HEU shall allow the engineer to increase that number in increments of one operative brake. If a discrepancy is found, the database must be cross-checked against the actual train configuration. After confirmation of the number of potentially operative brakes in the train, the HEU shall begin the train sequencing process without requiring additional input from the operator. The HEU shall provide a means to cancel/abort train sequencing in process and still allow RUN mode to be entered.

During Initialization mode, the network devices shall not transmit exception messages except for critical loss exceptions, PSC exceptions, and version compatibility exceptions per AAR Standard S-4230, latest revision.

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The engineer may cancel the initialization procedure at any time. If the initialization procedure is cancelled, the HEU returns to the setup process and/or allows the engineer to restart the initialization process. When Initialization mode is exited, all fault logic shall be reset.

2.2.3.1 Sequencing

The ECP system shall provide the ability to sequence the train during ECP system initialization. The lead HEU, as part of the initialization procedure, shall determine the relative position and orientation of each vehicle within the train with respect to the locomotive on which the HEU designated as lead is installed.

2.2.3.1.1 General sequencing requirements

The following are general requirements for sequencing.

1. All network devices shall provide an indication of their capability to perform the sequencing process during initialization.
2. The system shall be able to determine the sequential order of the vehicles in the train with an accuracy of ± 0 vehicles.
3. When sequencing is completed successfully, each vehicle shall retain its position and orientation.
4. Successful sequencing shall not be required for normal train operation.
5. Any failures related specifically to sequencing shall not affect normal train operation.
6. Sequencing shall not in any way inhibit the car's ability to maintain the requested train brake command as long as the CCD's battery has sufficient charge to operate the CCD.
7. Sequencing shall not be affected by a low battery on a CCD (one that can still power the CCD electronics, but would normally cause the CCD to shut down to conserve the battery).

2.2.3.1.2 Locomotive equipment requirements for sequencing

The sequencing requirements for locomotive equipment are met by the train line power supply and associated PSC, HEU, and locomotive ID device.

2.2.3.1.2.1 Train line power supply requirements for sequencing

The train line power supply shall contain the hardware necessary to support train sequencing as defined in Section 2.2.3.1.4, "Hardware Requirements for Sequencing."

2.2.3.1.2.2 Lead HEU requirements for sequencing

The HEU shall contain the software necessary to support train sequencing as defined in Sections 2.2.3.1.5, "General Software Requirements for Sequencing," and 2.2.3.1.6, "Process Steps for Sequencing."

2.2.3.1.2.3 Trailing locomotive requirements for sequencing

The HEU or the PSC on trailing locomotives shall contain the software necessary to support train sequencing as defined in Sections 2.2.3.1.5, "General Software Requirements for Sequencing," and 2.2.3.1.6, "Process Steps for Sequencing." If both the HEU and the PSC on a trailing locomotive indicates the capability to perform the sequencing process, the lead HEU shall select only one of the devices to perform the sequencing function for that vehicle.

2.2.3.1.2.4 Locomotive ID requirements for sequencing

The locomotive ID device shall contain the hardware and software necessary to support train sequencing as defined in Sections 2.2.3.1.4, "Hardware Requirements for Sequencing," 2.2.3.1.5, "General Software Requirements for Sequencing," and 2.2.3.1.6, "Process Steps for Sequencing."

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2.2.3.1.3 Car Equipment requirements for sequencing

The sequencing requirements for rail car equipment are met by the CCD and car ID device.

2.2.3.1.3.1 CCD requirements for sequencing

The CCD shall contain the software necessary to support train sequencing as defined in Sections 2.2.3.1.5, “General Software Requirements for Sequencing,” and 2.2.3.1.6, “Process Steps for Sequencing.”

2.2.3.1.3.2 Car ID requirements for sequencing

The car ID device shall contain the hardware and software necessary to support train sequencing as defined in Sections 2.2.3.1.4, “Hardware Requirements for Sequencing,” 2.2.3.1.5, “General Software Requirements for Sequencing,” and 2.2.3.1.6, “Process Steps for Sequencing.”

2.2.3.1.4 Hardware requirements for sequencing

2.2.3.1.4.1 Train line power supply requirements

The ECP train line power supply shall provide a nominal 24 Vdc output as defined in AAR Standard S-4220, “ECP Cable-Based Brake DC Power Supply—Performance Specification,” latest revision. This voltage shall be applied to the conductors of the train line during the sequencing process.

2.2.3.1.4.2 Switchable load requirements

The ECP equipment on each car and locomotive shall provide a switchable load across the two conductors of the train line. The switchable load, when activated, shall cause a DC current of $0.65\text{ A} \pm 0.1\text{ A}$ to flow between the load and the train line power supply with the train line voltage at 24 Vdc. The total AC impedance presented by the ECP equipment on a vehicle shall be nominally 2,000 ohms in the 100-KHz to 450-KHz frequency band when the load is not activated and shall not be reduced below 500 ohms when the load is connected. The default state of the switchable load shall be not activated. With no switchable load connected and the train line voltage less than 30 Vdc, train line current shall not exceed 0.17 mA per device.

2.2.3.1.4.3 Current sensing requirements

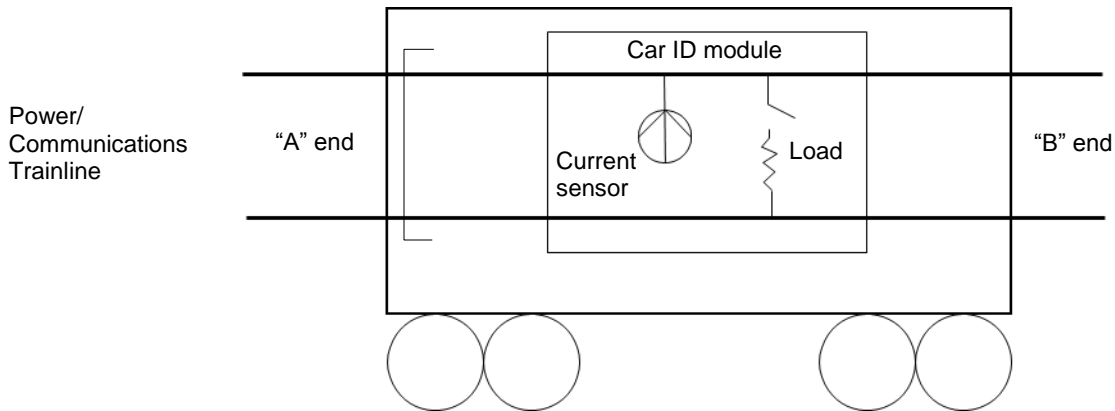
The ECP equipment on each car and locomotive (rail vehicle) shall be capable of sensing the train line current resulting from the activation of one switchable load as defined in Section 2.2.3.1.4.2, “Switchable Load Requirements,” when that rail vehicle is between the train line power supply and the activated switchable load. No current shall be sensed when the sensing vehicle is not between the train line power supply and the activated switchable load. The ECP current sensor shall not be damaged by current up to 15 A.

2.2.3.1.4.4 Car Hardware orientation

The default orientation of the current sensor and switchable load on each car relative to the A-end and the B-end shall be as shown in [Figure 2.2](#). If the opposite orientation is utilized, a parameter in the car ID shall be used to allow the CCD to invert the orientation data reported to the lead HEU.

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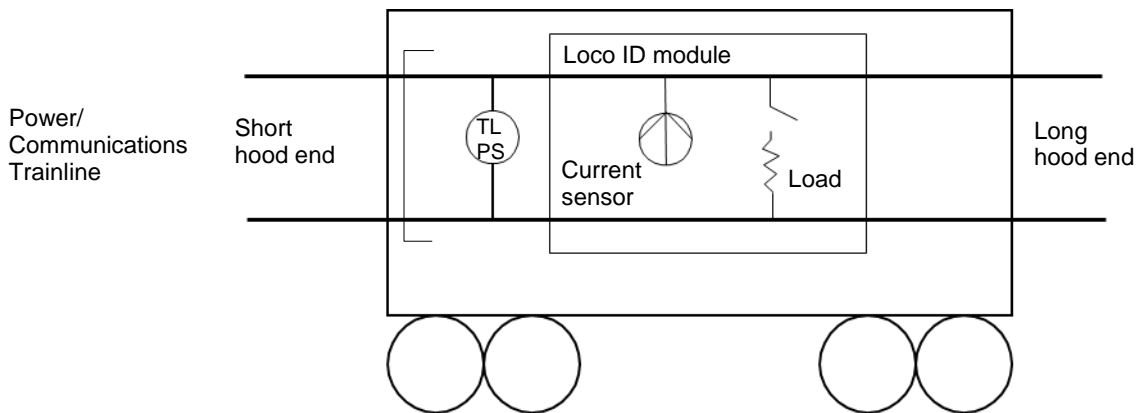
FIGURE 2.2
 Car Orientation



2.2.3.1.4.5 Locomotive hardware orientation

The orientation of the current sensor, switchable load, and train line power supply on each locomotive relative to the front (short-hood) and the rear (long-hood) shall be as shown in **Figure 2.3**. If the opposite orientation is utilized, a parameter in the locomotive ID shall be used to allow the locomotive equipment to invert the orientation data reported to the lead HEU.

FIGURE 2.3
 Locomotive Orientation



2.2.3.1.4.6 EOT hardware requirements for sequencing

When the train line voltage is less than 30 Vdc, the current drawn from the train line by the EOT shall not exceed 0.17 mA.

2.2.3.1.5 General Software Requirements for Sequencing

The CCD/car ID, HEU/locomotive ID, and optionally the PSC/locomotive ID shall provide the following functions to support sequencing:

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1. Connect load across the train line in response to lead HEU commands.
2. Provide a timing function to automatically disconnect the load after train line current has reached and maintained a level as specified in Section 2.2.3.1.4.2, “Switchable Load Requirements,” for a minimum of 200 ms and a maximum of 300 ms of continuous connection.
3. Detect a valid sequencing train line current pulse when sequencing is active. A valid current pulse shall be detected if train line current is at or above the limit as specified in Section 2.2.3.1.4.2, “Switchable Load Requirements,” for a minimum of 100 ms and a maximum of 400 ms continuous.
4. Maintain a lead locomotive sense status that is initialized to false and set to true if a valid sequencing train line current pulse is detected during the lead locomotive sense phase.
5. Maintain a pulse counter that is initialized to zero and incremented by one during the sequencing phase each time a valid train line current pulse is detected when this vehicle is not the one connecting its load.
6. Maintain a vehicle orientation status relative to the lead locomotive that is determined by detecting the presence/absence of train line current when this vehicle’s load is connected, comparing it to a car/locomotive ID parameter that identifies how the current sensor was installed on the vehicle, and reversing it if the lead locomotive sense status is set to true.
7. Determine the vehicle position based on the total number of vehicles sequenced, pulse count and lead locomotive sense status. If the lead locomotive sense status is set to true, the vehicle position shall be calculated as (pulse count + 1); otherwise the vehicle position shall be calculated as (number of vehicles sequenced – pulse count).
8. Report the sequencing results as defined in S-4230, latest revision, to the lead HEU when requested.

2.2.3.1.6 Process steps for sequencing

The lead HEU shall control the sequencing process via network commands to a PSC, trailing locomotives, and all cars. Prior to beginning the sequencing process, the HEU must have completed the process of identifying all network devices in the train and assigning them unique network addresses. The general process involves a preparation phase, a lead locomotive sense phase if necessary, a vehicle sequencing phase, and a data collection phase.

2.2.3.1.6.1 Sequencing preparation phase

The preparation phase is used to initialize devices for sequencing. The lead HEU shall use the following steps during this phase:

1. The HEU shall broadcast a Prepare for Sequencing command on the train line to initialize all participating devices for sequencing. In response to this command, the CCDs and EOT disable their normal low battery shutdown logic and participating devices reset their position count and orientation status to un-known and lead locomotive sense status to false.
2. The HEU shall command 230 Vdc train line power to off.
3. If train line voltage is not less than 10 Vdc after 30 seconds, then the system shall provide an operator indication/warning that sequencing is not available and shall abort the sequencing process. After verifying that train line voltage is less than 10 Vdc, the HEU shall command the lead PSC to energize 24 Vdc train line power.
4. After a minimum of 5 seconds, the HEU shall verify that 24 Vdc is present on the train line.
5. After verifying that 24 Vdc is present on the train line, if the enabled PSC is on the lead locomotive, the HEU shall begin the vehicle sequencing phase; otherwise it shall begin the lead locomotive sense phase

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2.2.3.1.6.2 Preparation phase message summary

- | | | |
|----|---------------------|------------------------|
| 1. | HEU -> All Vehicles | Prepare for Sequencing |
| 2. | HEU -> All PSCs | Deactivate 230 Vdc |
| 3. | HEU -> One PSC | Activate 24 Vdc |

2.2.3.1.6.3 Lead locomotive sense phase

This phase is required if a non-lead locomotive train line power supply and associated PSC are used for providing the train line voltage for sequencing. The lead HEU shall use the following steps during this phase:

- | | |
|----|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1. | The HEU shall broadcast an Enable Lead Sense command on the train line to enable the lead sense function on all participating devices. |
| 2. | The HEU commands the load on the lead locomotive to be connected across the train line. |
| 3. | The load on the lead locomotive shall be connected and removed as defined in Section 2.2.3.1.5, “General Software Requirements for Sequencing.” |
| 4. | All participating trailing devices shall read their current sensor and update their lead locomotive sense status as defined in Section 2.2.3.1.5, “General Software Requirements for Sequencing.” |
| 5. | Steps 2. through 4.) may be repeated up to two times to minimize the possibility of errors. |

2.2.3.1.6.4 Vehicle sequencing phase

During this phase, each car and locomotive determines its relative position and orientation. The lead HEU shall use the following steps during this phase:

- | | |
|----|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1. | The HEU commands all participating devices to start counting current pulses. |
| 2. | The HEU commands a trailing device to connect its load across the train line. |
| 3. | The load on the trailing device shall be connected and removed as defined in Section 2.2.3.1.5, “General Software Requirements for Sequencing.” The associated network device shall respond with a Load Connected message. |
| 4. | All trailing devices participating in sequencing shall read their current sensor and update their sequencing information as defined in Section 2.2.3.1.5, “General Software Requirements for Sequencing.” |
| 5. | A minimum of 50 ms and a maximum of 150 ms after the load has been disconnected, the device shall send a Load Removed message to the HEU. |
| 6. | The HEU waits a minimum of 50 ms. |
| 7. | The HEU repeats steps 2. through 6. for each vehicle in the train database. |
| 8. | The HEU commands all train line devices to stop counting pulses. |

2.2.3.1.6.5 Vehicle sequencing phase message summary

- | | |
|----|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1. | HEU -> All Vehicles Start Pulse Count |
| 2. | For each Vehicle(i) where (i=1,# of vehicles in train database):
a. HEU -> Vehicle(i) Connect Load
b. HEU <- Vehicle(i) Load Connected
c. HEU <- Vehicle(i) Load Removed |
| 3. | HEU -> All Vehicles Stop Pulse Count |

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2.2.3.1.6.6 Data collection phase

The last phase is where each car and locomotive reports its sequencing results to the lead HEU. The HEU shall use the following steps during this phase:

1. The HEU shall query each vehicle for its position count, orientation, and other sequencing information as defined in AAR Standard S-4230, latest revision.
2. After all vehicles have been queried for their sequencing results, the HEU shall broadcast an End Sequencing command to all train line devices. In response to this command, the CCDs and EOT enable their normal low battery shutdown logic.
3. After sequencing is complete, the HEU can resume normal control of train line power.

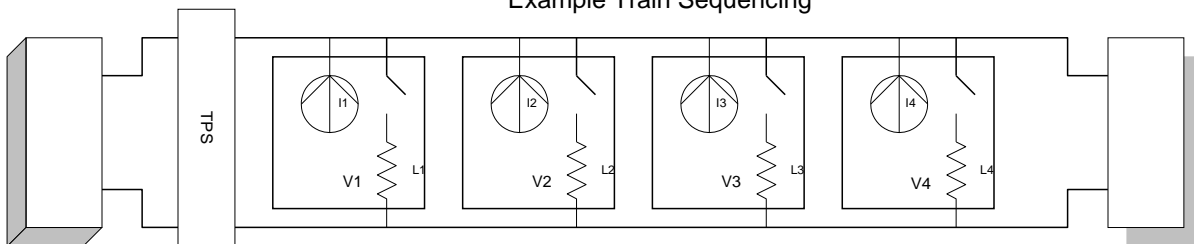
NOTE: The lead HEU may, at the option of its manufacturer, resume normal control of train line power prior to sending the queries to each vehicle for its sequencing data.

2.2.3.1.6.7 Data collection phase message summary

1. For each Vehicle(i) where (i=1,# of vehicles in train database):
 - a. HEU -> Vehicle(i) Query Sequencing Results
 - b. HEU <- Vehicle(i) Position Count and Orientation
2. HEU -> All Vehicles End Sequencing
3. HEU -> PSC Turn Off 24 Vdc
4. HEU -> Any PSC Activate 230 Vdc

NOTE: The lead HEU may, at the option of its manufacturer, resume normal control of train line power prior to sending the queries to each vehicle for its sequencing data.

FIGURE 2.4
Example Train Sequencing



Consider a sample train consist as shown electrically in **Figure 2.4**. This train has four vehicles. The HEU performs four iterations during the vehicle sequencing phase. During each iteration, only one vehicle connects a load across the train line. All vehicles detect the presence or absence of current and keep count of the number of times current was detected. This information is stored in “Pulse Count” at each vehicle. The vehicle’s actual position is based on the value of “Pulse Count” and the total number of vehicles in the train consist.

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TABLE 2.1
Train Sequencing Example

Load Connected / Iteration	I1 / V1	I2 / V2	I3 / V3	I4 / V4
L4	present(1)	present(1)	present(1)	Note 1
L3	present(1)	present(1)	Note 1	absent(0)
L2	present(1)	Note 1	absent(0)	absent(0)
L1	Note 1	absent(0)	absent(0)	absent(0)
Pulse Count	3	2	1	0
Position (#Vehicles–Count)	1	2	3	4

Note 1: Vehicle that connected its load does not update its pulse count.

2.2.3.2 Completion of initialization mode

Before the full-service interlock is allowed to clear, the HEU shall attempt to query the status of all CCDs. If the HEU detects, based on status information, that a CCD has a problem, then the HEU shall warn the engineer and the engineer may cut out the CCD. To clear the full-service interlock and operate in RUN mode, the engineer’s brake controller must be in the full-service position.

2.2.3.3 Operable brakes

Locomotives and cars (including cab cars) shall be included in the percent operable brake calculation.

Each locomotive axle, on locomotives weighing more than 200,000 lbs, shall count as two car axles in the percent operable calculation.

ECP for passenger-equipped vehicles may support cutout brake detection to the level of operator intervention.

NOTE: Passenger vehicles typically allow for the isolation of each truck.

The lead head end unit (HEU) shall account for such fractional degradations in its percent operable calculation.

2.2.4 System diagnostics and testing

The passenger ECP system shall successfully pass all applicable tests defined in the APTA Single Car Test APTA PR-M-S-005-98 latest revision.

An ECPB system diagnostic test may be requested by the engineer interacting with the HEU. Functions of the ECPB system diagnostic test include the following:

2.2.4.1 Train Line Power Supply Tests

2.2.4.1.1 This test shall be available during RUN mode while the train is stopped, train line power is on, and at least a full service brake is being commanded by the HEU. Activation of train line power during this test shall be in accordance with Section 2.3.3.1.2. To complete this test, EOT beacons and head end termination must be continuously present.

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This test shall verify the following:

- That each train line power supply in the train can be activated as a Primary power supply for providing 230 Vdc train line power (see Section 2.3.3.2.1 and 2.3.3.3.2.1).
- That each train line power supply in the train can be activated as a Secondary power supply for providing 230 Vdc train line power (see Section 2.3.3.2.2).
- That all available train line power supplies can be activated together to provide 230 Vdc train line power continuously throughout the train.
- That the Lead train line power supply can provide 24 Vdc for sequencing. To perform the Train Line Power Supply test, the HEU shall do the following:

1. Command train line power off.
2. Command the CCDs to low power mode.
3. Command 230 Vdc train line power on.
4. Enable a single train line power supply as Primary.
5. Enable the other train line power supplies as Secondaries.
6. Wait at least 15 seconds for the train line voltage/current to stabilize.
7. Command the CCDs to Normal power mode.
8. Verify that train line voltage at each train line supply is at least 210 Vdc.
9. Verify that train line voltage at the EOT is at least 100 Vdc.
10. Repeat steps 1 through 9 for each train line power supply in the train
11. Command train line power off.
12. Enable the lead train line power supply to provide 24 Vdc.
13. Verify that train line voltage at the EOT is at least 20 Vdc and less than 30 Vdc.
14. Command 230 Vdc train line power on.

2.2.4.1.2 At the conclusion of the Train Line Power Supply test, the following information shall be made available to the operator:

- Number of train line power supplies tested
- Any train line power problems detected
- Any problem with the lead power supply providing 24 Vdc

2.2.4.2 CCD/EOT Battery Tests

When operating in passenger ECP mode, the battery diagnostic test is not required to be supported by the car control devices (CCDs) and may be misleading due to the presence of the local car battery power source.

The purpose of this test is to identify any CCDs or EOT with batteries that are low on charge, are missing, or need replacing. This test shall be available during RUN mode while the train is stopped and at least a full service brake is being commanded by the HEU. Activation of train line power during this test shall be in accordance with Section 2.3.3.1.2.

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To perform the CCD/EOT battery test, the HEU shall do the following:

1. Ensure that train line power is on continuously for 30 minutes.
2. Query each CCD for status while train line power is on.
3. Command train line power off.
4. After train line power has been off for 60 seconds, query each CCD for status.
5. Command train line power back on.

At the conclusion of the CCD/EOT battery test, the HEU shall provide the following information to the operator:

- Number of CCDs tested
- Car reporting mark of any CCDs with a potential bad or missing battery (CCDs that responded to the HEU query while train line power was on in step 2 of the test, but did not respond to the HEU query when train line power was off in step 4)
- Car reporting mark of any CCDs reporting a Low Battery condition with train line power off
- EOT battery status

2.2.4.3 Train snapshot

Since the CCDs have local car battery power, the trainline snapshot test will indicate that the CCD is receiving power; not necessarily trainline power.

The Train Snapshot is a diagnostic feature that is intended to provide the engineer and maintenance personnel with a snapshot of the current ECP status of the train. The Train Snapshot function shall be available during RUN mode while the train is stopped and at least a full service brake is being commanded by the HEU. The Train Snapshot may be performed with train line power either ON or OFF.

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The Train Snapshot function shall determine and make available to the operator the following information:

1. The number of ECP-equipped locomotives in the train that are communicating with the HEU
2. The number of ECP train line power supplies in the train that are communicating with the HEU
3. The number of CCDs in the train that are communicating with the HEU
4. The number of CCDs reporting train line power ON
5. The number of CCDs counting as Inoperative
6. The number of CCDs reporting brake pipe pressure below the Loss of BP exception threshold as defined in Section 2.4.3.3
7. The number of CCDs reporting reservoir pressure below the Low Reservoir exception threshold as defined in Section 2.4.6
8. The number of CCDs reporting battery charged at or below the Low Battery exception threshold as defined in Section 2.4.8
9. The EOT device as one of EOT, LOCO, PLUG, or NONE based on the following:
 - EOT if a standalone end-of-train device is present
 - LOCO if a locomotive is acting as an EOT device
 - PLUG if a train line termination plug is sending EOT beacons
 - NONE if no EOT beacons are detected
10. The status of the EOT as one of BATT OK or LOW BATT based on the following:
 - BATT OK if the EOT device is reporting battery not low
 - LOW BATT if the EOT device is reporting a low battery

Example Scenario:

- Actual Train Configuration #1
- 3 ECP-equipped locomotives (1 HEU and 1 TPS per locomotive)
 - 100 ECP-equipped car singles (1 CCD per car)
 - EOT device

Train Snapshot report to the engineer:

TRAIN SUMMARY:	
# of ECP Locomotives Reporting	3
# of ECP Train line Power Supplies	3
# of CCDs Reporting	100
# of CCDs Reporting Train Line Power ON	100
# of Inoperative CCDs	0
# of CCDs Reporting Brake Pipe Pressure Low	0
# of CCDs Reporting Reservoir Pressure Low	0
# of CCDs Reporting Battery Low	0
EOT Device	EOT
EOT Status	BATT OK

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2.2.5 RUN mode

2.2.5.1 Description

RUN mode is the main mode of operation of the ECP brake system and is selected when the train consist is fully configured and ready for normal road operations. As such, all fault detection modes are enabled to permit safe operation of trains at full speed.

2.2.5.2 Normal Operational Procedures

The following describes the normal sequence of operation in RUN mode. Section 2.2.5.3, “Fault Detection and Response Procedures,” describes fault detection and response operations.

2.2.5.2.1 Run Mode Brake Control

RUN mode brake control provides the full functionality of the ECP brake system for road operations. The RUN mode brake control includes the following:

Note that the passenger ECP EOT may not report the BPP.

1. The engineer’s brake command is read from the man-machine interface, translated by the HEU to train brake commands (TBCs), and broadcast to all network devices as part of the HEU beacon message.
2. HEU shall broadcast a “configuration” message containing BPP setpoint, and other information (reference AAR Standard S-4230, latest revision), as follows:
 - every time “setup” is changed
 - once every 120 seconds
3. If an emergency command (TBC = 120%) is made, a 120-second emergency interlock timer is started.
4. If an emergency command is in effect, the HEU shall not release it until the 120-second interlock has expired. If the emergency brake application is in response to a fault condition, it shall additionally be maintained until the fault condition is removed or cleared or the operating mode changed.
5. If a release from emergency is requested, the engineer must place the control to the full-service position. Once the emergency interlock has expired, release from emergency shall be enabled unless a fault condition still exists. Release from emergency shall go directly to full service.
6. If a full or partial release from the current brake application is selected, the TBC transmitted shall reflect the control input unless a penalty brake application, an emergency, or a full-service interlock is active.
7. HEU train brake commands (TBC) are expressed as a percentage [0% (release), 10% (minimum service) to 100% (full service), in increments of 1%] of full-service braking force, plus 0% for full release and 120% for emergency. They are transmitted by the HEU once per second as part of the priority HEU beacon message. An emergency brake command shall be transmitted immediately when required and repeated once per second thereafter.
8. The HEU beacon is broadcast and includes the current operating mode, TBC, train line power on/off, and network device status query (Section 2.3.17.1.2). Other HEU commands or information may be transmitted, as well. See Section 2.3.17.8, “Control Messages.”
9. A CCD may automatically cut out/in under the conditions described in Section 2.3.12.
10. CCD BCP control: CCDs use their preprogrammed braking constant C (and other parameters that may be required) with the accepted load data to give the proper BCP in response to each TBC. See Sections 2.3.4 through 2.3.11 for performance requirements of BCP response.
11. EOT transmits beacon to HEU: The EOT status beacon shall be transmitted to the HEU once per second and may include BPP, percentage of full battery charge, and other data. See Section 2.3.17.4, “EOT Beacon/Status Message.”

2.2.5.3 Fault Detection and Response Procedures

The following describes the sequence of operation for detecting and responding to various component and system faults in RUN mode:

2.2.5.3.1 General Fault Classification

2.2.5.3.1.1 Faults are categorized according to type and severity of fault and according to which major component is responsible for its detection and handling.

2.2.5.3.1.2 General fault types are outlined in Section 2.2.5.3.1.3 in order of severity. They comprise three basic classes of faults:

- The first class of faults is the most severe, and includes those faults that are likely to jeopardize safety. These faults must result in an immediate automatic emergency brake application.
- The second class of faults is somewhat less severe, and must result in an immediate automatic full service (or penalty brake application).
- The least severe fault class must result in a warning to the engineer, but must not significantly interfere with the normal operation of the brake system.

2.2.5.3.1.3 Note that some faults are compound faults (meaning a coincidence of two or more faults).

Automatic Emergency

- Critical system loss (loss of BPP or communication)

Automatic Full Service

- Less than 50% operative brakes, causes for which include low battery charge, low reservoir charge, CCD shut down, CCD cutout, and other disabling faults
- Low EOT battery charge
- Multiple lead (active) HEUs

Warning Only

- Low train line voltage
- High train line voltage
- Incorrect BCP
- Low EOT BPP
- Percentage of operative brakes falls below 85% or 75%

NOTE: In the passenger ECP application, the cars may have access to the local car battery and will be able to maintain functionality without trainline power via available local car battery.

NOTE: It is expected that brake pipe (BP) may not consistently remain charged in ECP. As a result the ECP system shall not generate faults should a Brake Pipe service reductions be detected.

NOTE: In the passenger operating mode, the system will not enforce an ECP penalty application if a pneumatic brake application is commanded by the electronic air brake (EAB)

2.2.5.3.2 HEU Fault Detection, Response, and Recovery

The HEU shall perform fault detection and response procedures as described in Section 2.4.

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2.2.5.3.3 CCD Fault Detection and Response

CCDs shall perform fault detection and response procedures as described in Section 2.4.

2.2.5.3.4 EOT Fault Detection and Response

The EOT shall perform fault detection and response procedures as described in Section 2.4.

2.2.5.3.5 PSC Fault Detection and Response

The PSC shall perform fault detection and response procedures as described in Section 2.4.

2.2.5.4 Train Line Termination Plug

The purpose of the train line termination plug is to allow ECP Operation with train line power on continuously without an ECP EOT being present. A Train line Termination Plug may be used in place of an ECP EOT to allow train line power to remain on continuously. Train movement in RUN mode with a Train line Termination Plug shall not be allowed and is accomplished by not allowing the train brake to be released based on the HEU detecting EOT Low Battery Charge (Section 2.4.10.4).

2.2.5.4.1 The requirements of the train line termination plug are as follows:

- It shall not have a battery.
- It shall not have a marking device /light.
- It shall not detect motion.
- It shall not connect to the brake pipe.
- It shall read train line voltage.
- Within 2 seconds of the train line voltage reaching 100 Vdc, the train line termination plug shall activate and begin sending the EOT beacon.
- The train line termination plug shall deactivate when train line power transitions below 100 Vdc.
- The train line termination plug shall draw less than 0.17 mA when train line voltage is 30 V and below.
- A train line termination circuit shall be provided.
- The EOT beacon sent by the train line termination plug shall include the following:
 - Brake pipe pressure of 254 psi
 - Marking device/light of Unknown
 - Motion detected of Unknown
 - Battery charge of 0%
 - Battery status of Not Charged
 - Train line voltage

2.2.6 CUTOUT mode

The HEU shall wait until the brake pipe has dropped below 25 psi at the HEU before indicating CUTOUT mode in the HEU beacon.

NOTE: As CCDs will revert to emulation when ECP ends, this requirement will prevent the failure mode of releasing brakes if ECP is ended and BP is charged.

2.2.7 All modes

2.2.7.1 Description

This section lists functions and features that must be present in all ECP brake system modes of operation when applicable. Refer to Section 2.3 for detailed functional descriptions.

2.2.7.2 Functions and Features Applicable to All Modes of Operation

1. HEU cab displays and controls (engineer interface) include the following:
 - Normal displays (see Section 2.3.1.1)
 - Warnings and indications (see Section 2.3.1.2)
 - Engineer controls (see Section 2.3.1.3)
2. Manual brake cylinder and reservoir venting
3. Pneumatic backup (see Section 2.3.18)
4. Multiple lead HEUs on the network (see Section 2.4.11)
5. A CCD shall be activated by presence of train line power.
6. An EOT shall be activated by the presence of train line power.
7. Continuous reservoir charging (see Section 2.3.19)

NOTE: In addition to trainline power, the brake system on the car may have access to the local car battery/power system and will remain activated in the absence of trainline power. The EOT may also have access to the local car battery/power.

2.2.8 Passenger emulation mode

Passenger emulation mode allows an ECP-equipped car to perform like a standard pneumatic car. The following section defines the requirements for transitioning between ECP and emulation mode for ECP cars.

2.2.8.1 Entering passenger emulation

1. Entering passenger emulation from power-up: Upon power-up, if the CCD has not established a connection to a lead HEU per AAR Standard S-4200, Section 2.5.1.2, then the CCD shall enter emulation mode within 10 seconds.
2. Entering passenger emulation when ECP is CUTOFF: When the CCD receives HEU beacons from the connected lead HEU indicating CUTOFF mode, the CCD shall enter emulation mode and default to the brake pipe pressure set point indicated in the last train dynamic config message received when in ECP mode.
3. Entering passenger emulation on critical loss: The CCD shall stop responding to HEU commands and enter emulation mode when it has detected a loss of HEU and the brake pipe pressure is below 25 psi. The CCD shall default to the brake pipe pressure set point indicated in the last train dynamic config message received when in ECP mode. If the brake pipe does not drop below 25 psi, then the vehicle shall maintain the last ECP brake application.

2.2.8.2 Entering ECP operation

A CCD shall enter ECP operation when a connection to a lead HEU has been established per Section 2.5.1.2.

2.2.8.3 Emulation performance

When operating in emulation mode, the passenger cars shall make brake applications based on changes in brake pipe pressure. The car shall support both graduated and direct release. The 26C emulation performance is defined in APTA document (TBD).

When operating in emulation mode, the CCD shall be capable of responding to the snow brake command from the locomotive if the car is so equipped.

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2.3 Normal operating functions

2.3.1 Cab displays and controls

The ECP brake system engineer interface (controls, displays, and alarms) may be provided directly by the HEU or via the locomotive system integration interface, and shall include the following features and functions:

2.3.1.1 Normal displays

Information normally displayed in the lead locomotive shall include the following:

1. Percentage brake command (current TBC)
2. Current EOT BPP (if provided and valid in EOT beacon), updated once per second
 - a. If the EOT beacon's brake pipe pressure is 254 psi, then the EOT BPP will be displayed as TTP. This is an indication that a train line termination plug (Section 2.2.5.4) is sending the EOT beacon.
3. Percentage operating brakes
4. Train line power status to include the following:
 - a. Train line power command/status (ON, OFF, AUTO, or 24 V)
 - b. If an EOT is present, the ECP display shall provide an indication that train line power is ON/OFF at the EOT.
 - c. The ECP display shall provide an indication if train line power is not continuous throughout the train.
5. Total potentially operative brakes
6. At least the following car status data for any car requested (Section 2.3.17.3):
 - a. CCD Cut-In/Cut-Out Status
 - b. Brake Pipe Pressure
 - c. Reservoir Pressure
 - d. Brake Cylinder Pressure
 - e. Percentage of Car Load
 - f. Battery Percentage Charged
 - g. Train Line Power Status
 - h. Empty / Load Device Type (None Installed, Mechanical Device, Electronic Device)
7. Operating mode
8. Train Brake Effort (TBE): An average of the train's car braking effort as reported by each CCD shall be displayed during RUN mode (Section 2.3.18.3.1).

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2.3.1.2 Warnings and indications

Warnings are generally not required when an individual CCD has malfunctioned or ceases operation. Warnings and indications shall include the following:

1. Warn of absence of EOT beacon (Section 2.4.2.1)
2. Low battery charge on EOT (Section 2.4.8.4)
3. Warn of less than 95%, 90%, 85%, 75%, and 50% operative brakes in train (Section 2.4.5). This is an acknowledged warning.
4. Warn of low train line voltage (Section 2.4.7). This is an acknowledged warning.
5. Warn of critical loss reported by two or more network devices (Section 2.4.4)
6. Warn of HEU shutdown resulting from uncontrolled signal transmissions from a transceiver (Section 2.4.2.7)
7. Warn of multiple lead (active) HEUs in the network (Section 2.4.11)
8. Warn of presence of more than 30 Vdc on the train line when power is off. This is an acknowledged warning. (Section 2.4.9)
9. Warn of CCD with incorrect BCP. This is an acknowledged warning. (Section 2.4.10.2)

2.3.1.3 Engineer Controls

2.3.1.3.1 HEU brake control shall provide the following brake commands and functions. Each function must be available or accessible in one operator motion from any other function.

- Minimum service (10% application)
- Full service (100% application)
- Emergency (120% application)
- Full release (0% application)
- Graduated applications and releases in 1% increments between 10% and 100% full-service application.
- Suppression (when applicable)
- Acknowledgement (when applicable)

2.3.1.3.2 Means of implementation of other required inputs shall be manufacturer specific.

2.3.1.4 Interaction with locomotive systems/signals

NOTE: In the event of a safety system penalty, BP may reduce to or beyond a failsafe application.

The HEU should be capable of responding to or generating the following locomotive system signals:

1. Alerter (see Section 2.3.1.4.1)
2. PCS /PCR (see Section 2.3.1.4.2)
3. Cab Signal / Over Speed (see Section 2.3.1.4.3)
4. Suppression (see Section 2.3.1.4.3)

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2.3.1.4.1 Alerter (Safety Control Magnet Valve)

The HEU shall be capable of detecting a conventional penalty brake application initiated from the safety control magnet valve or similar device if the locomotive is so equipped. On detection of a penalty brake application from this device, the HEU shall increase the current electronic brake application to at least 100% brake command for as long as the penalty remains in effect.

2.3.1.4.2 PCS/PCR

The HEU shall be capable of sending the locomotive a signal that will unload the engine. This signal shall be asserted on any electronic emergency and ECPB automatic electronic penalty application, which includes the system fault-initiated brake applications listed in Section 2.4.1, and shall remain asserted until the application has been released.

2.3.1.4.3 Cab Signal /Over Speed

The HEU shall be capable of detecting brake applications initiated by the train control system such as positive train control (PTC), cab signal/overspeed systems. The HEU may treat PTC initiated applications as a cab signal/overspeed application per this section.

2.3.1.4.3.1 The HEU shall be capable of detecting a conventional penalty brake application initiated from the cab signal magnet valve or similar device if the locomotive is so equipped. On detection of a penalty brake application from this device, the HEU shall increase the current electronic brake application to at least 100% brake command for as long as the penalty remains in effect.

2.3.1.4.3.2 In addition, the HEU shall provide a means of providing to the locomotive cab signal equipment (if the locomotive is so equipped) a signal indicating that an electronic suppression application has been made by the engineer.

2.3.1.4.3.3 The suppression signal to the cab signal equipment shall be a fault tolerant system, since a false suppression signal from the HEU will render the cab signal system unable to stop the train in the event of a fault.

2.3.1.4.3.4 The Train Brake Command shall be independently monitored to ensure that Cab Signal Penalties are properly enforced in the event of a failure and that an pneumatic emergency, ECP emergency or penalty application is independently commanded.

2.3.1.5 Locomotive retardation during ECP braking

The passenger ECP system shall support locomotive braking in response to ECP commands.

2.3.1.5.1 The requirements for locomotive retardation during ECP braking shall be railroad specific in that not all railroads may want automatic locomotive brake cylinder pressure control or dynamic braking during ECP brake applications (e.g., railroads that always bail off automatic brake applications). The requirement to provide the ability to have locomotive retardation during ECP brake applications shall not preclude manufacturers and railroads from developing other braking systems that meet the intent of providing appropriate locomotive retardation in conjunction with ECP train braking as long as these systems allow for interoperability between locomotives equipped with different manufacturers' ECP equipment.

2.3.1.5.2 The requirements for control of locomotive retardation during ECP braking will normally apply to the ECP equipment on the lead locomotive and to the controlling locomotive in a remote, distributed power locomotive consist. All other locomotives normally will be controlled via existing locomotive multiple-unit (MU) cables and pipes.

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2.3.2 Communication network test

Testing of network communication integrity may be performed during RUN mode and at other times at the discretion of the manufacturer. The test may include evaluation of error rates and/or analysis of signal attenuation through the network.

2.3.2.1 To aid in system diagnostics, CCDs, PSCs, and EOTs shall maintain a count of CRC errors detected by the communication network controller. This count shall be reset to zero at power-up and once per hour by the HEU. Each CCD/PSC/EOT shall set a flag in its status report if the CRC error count exceeds a threshold broadcast by the HEU. The HEU may use this information to identify malfunctioning network devices or groups of network devices.

2.3.2.2 To aid in system diagnostic services, the HEU may provide a means to measure the communication signal voltage level at its interface to the communication medium. If provided, the HEU shall make this measurement with a relative resolution of ± 0.5 dB over a minimum 50 dB dynamic range. The hardware that provides this measurement shall have no adverse effect on the communication signal. Determination of train line faults shall be manufacturer specific. A special “quiet” state shall be available when the train is stopped and holding a full-service interlock as defined in AAR Standard S-4230, latest revision.

2.3.3 Train line power control

Train Line Power shall be controlled by the HEU via commands to the PSCs and a power control flag in the HEU beacon. The HEU power control shall be derived from a combination of engineer input and other mode and fault data as defined in this section.

2.3.3.1 Train Line Power Mode Control

The engineer shall be permitted to select the train line power mode at any time. There shall be two engineer-selectable train line power modes: OFF and AUTOMATIC. The default train line power mode shall be OFF. The HEU may change the train line power mode from AUTOMATIC to OFF as defined in Section 2.3.3.1.2.

2.3.3.1.1 Power OFF Mode

When the Power OFF mode is selected or entered automatically, the HEU shall disable all power supplies in the train by setting the power control flag in the HEU beacon to the OFF state. All PSCs shall disable their associated train line power outputs when the power control flag in the HEU beacon is set to OFF.

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2.3.3.1.2 AUTOMATIC Power Mode

When AUTOMATIC power mode has been selected, the action performed by the HEU shall be as defined below:

1. When transitioning from OFF to AUTOMATIC mode:
 - A. The HEU shall provide a warning indicating train line power will be applied.
 - B. After the engineer has acknowledged the warning, the HEU shall request a confirmation that all personnel are clear from the train line.
 - C. After receiving this confirmation, the HEU shall command train line power to be activated. If the head end termination and EOT are not detected within 8 seconds after train line voltage has exceeded 30 Vdc at the activated PSC, the HEU shall automatically command that power be disabled.
2. If the head end termination is present and the HEU has received one or more EOT beacons in the last 6 seconds, it shall command that train line power be on continuously until one or more of the following occurs:
 - A loss of EOT is detected
 - A loss of head end termination is detected
 - A disabling train line power fault is detected
 - The engineer commands train line power OFF
 - The HEU commands train line power OFF during diagnostic tests
3. If train line power is commanded to OFF by the engineer, reactivation of train line power shall require the engineer to command the train line power mode to AUTOMATIC.
4. If train line power is shut down due to a loss of EOT communications, loss of head end termination, or disabling fault condition, the train line power mode shall continue to be AUTOMATIC with train line power commanded to OFF. While the train line power mode is AUTOMATIC, train line power may be re-enabled by the HEU without operator intervention. Note that there are fault conditions that would not allow power to be automatically re-enabled and turned ON.

While in AUTOMATIC mode, if a loss of EOT communications or loss of head end termination is detected for more than 30 seconds, train line power control shall revert to the Power OFF mode, and reactivation of train line power shall require the engineer to command the train line power mode to AUTOMATIC.

2.3.3.2 Train Line Power Supply Controller (PSC) Interface to HEU

The PSC shall provide a control and status interface to the HEU via the train line in accordance with the requirements of AAR Standard S-4220, “ECP Cable-Based Brake DC Power Supply—Performance Specification,” latest revision, and AAR Standard S-4230, “Intratrains Communication Specification for Cable-Based Freight Train Control Systems,” latest revision. This interface shall provide the functions identified in this section.

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2.3.3.2.1 Enable Train Line Power as Primary Power Supply

1. A PSC shall determine and indicate to the lead HEU that it is available as a primary train line power supply only if all of the following conditions are true:
 - A. Train line voltage measured at the PSC is less than 10 Vdc with either polarity.
 - B. The PSC has received one or more HEU beacons in the last 6 seconds.
 - C. The PSC has not detected a disabling fault (e.g., very low input voltage from the locomotive).
 - D. The PSC has not been commanded to a cut-out state by the HEU.
2. A PSC shall enable its associated train line power supply as the primary train line power supply when the following conditions are true:
 - A. A PSC has determined that it is available as a primary train line power supply.
 - B. The last HEU beacon received has the power control flag set to ON.
 - C. The PSC has received an individual command from the HEU to enable the train line power supply as a primary after the HEU beacon power control flag was set to ON.

2.3.3.2.2 Enable Train Line Power as Secondary Power Supply

1. A PSC shall determine and indicate to the lead HEU that it is available as a secondary train line power supply only if all of the following conditions are true:
 - A. Train line voltage measured at the PSC is greater than 50 Vdc with a detectable DC polarity.
 - B. The PSC has received one or more HEU beacons in the last 6 seconds.
 - C. The PSC has not detected a disabling fault (e.g., very low input voltage from the locomotive).
 - D. The PSC has not been commanded to a cut-out state by the HEU.
2. A PSC shall enable its associated train line power supply as a secondary train line power supply when the following conditions are true:
 - A. A PSC has determined that it is available as a secondary train line power supply.
 - B. The last HEU beacon received has the power control flag set to ON.
 - C. The PSC has received an individual command from the HEU to enable the train line power supply as a secondary after the HEU beacon power control flag was set to ON.

2.3.3.2.2.1 Load-Sharing Capable Train Line Power Supply

All train line power supplies shall be load-sharing capable.

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2.3.3.2.3 Disable Train Line Power

1. A PSC shall automatically disable its associated train line power supply output if any of the following conditions are true:
 - A. The PSC has received no HEU beacons in the last 6 seconds.
 - B. The HEU beacon has the power control flag set to OFF.
 - C. The PSC receives a command from the HEU to disable train line power.
 - D. The PSC detects a disabling fault (e.g., uncontrolled signal transmissions, very low input voltage from the locomotive). The PSC shall then send an exception message to the HEU.
 - E. The PSC detects less than 100 Vdc \pm 4% at its output while supplying its maximum rated current output (i.e., shorted train line). The PSC shall then send an exception message to the HEU.
 - F. The PSC upon being enabled as primary detects less than 110 Vdc at its output within 10 seconds after receipt of the enable command. The PSC shall then send an exception message to the HEU.
 - G. The PSC upon being enabled as secondary detects that it is not properly sharing the train line load at its output within 10 seconds after the receipt of the enable command. The PSC shall then send an exception message to the HEU.

2.3.3.2.4 PSC Status Flags for Power Management

1. A PSC shall provide the following flags in its status response to allow the HEU to manage train line power:
 - A. Available for use as the primary train line power supply (see Section 2.3.3.2.1).
 - B. Available for use as a secondary train line power supply (see Sections Section 2.3.3.2.2 and Section 2.3.3.2.2.1).
 - C. Train line power supply input voltage below locomotive specific threshold. This shall be a threshold voltage defined in the locomotive ID module to indicate the inability of the locomotive electrical system to continuously operate a train line power supply at rated output. The locomotive ID module shall also include a second, higher threshold value to provide hysteresis for this flag. The default values for these threshold voltages shall be 50 V and 60 V.
2. The remaining PSC status response data shall be as defined in Section 2.3.17.5.

2.3.3.3 HEU Train Line Power Management

The HEU shall provide a control and status interface to the PSC via the train line in accordance with the requirements of AAR Standard S-4230, “Intrain Communication Specification for

Cable-Based Freight Train Control Systems,” latest revision. This interface shall provide the functions identified in this section.

2.3.3.3.1 Train Line Power On/Off Control

The HEU shall control the on/off state of the train line power supplies via the power control flag in the HEU beacon and individual commands to PSCs. The power control flag in the HEU beacon when set to the OFF state shall disable all PSCs as a group and prevent them from responding to enable commands. A command to disable individual PSCs also shall be available. Individual commands shall be used to enable a PSC when the power control flag in the HEU is set to the ON state. An enable command to secondary PSC(s) shall be sent only after the primary was successfully activated.

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2.3.3.3.2 Locomotive Power Management

The HEU may optionally utilize the PSC status responses to select PSCs to operate the ECP train line while minimizing the effect of the ECP system on the locomotive power system. The HEU may utilize the following criteria in determining PSCs to enable:

1. If a PSC indicates that its input voltage is below the locomotive specific threshold, it shall not be enabled if there is any other PSC available with input voltage above the threshold.
2. If multiple PSCs indicate input voltage above the locomotive specific threshold, the HEU may select PSCs based on the results of the ECP diagnostic test or other data. The criteria could include the following:
 - A. PSC located on a locomotive other than the lead. This accounts for the likelihood that the lead locomotive has a larger electrical load for other than the ECP system.
 - B. PSC that provided the highest average EOT and lead locomotive measured train line voltage during diagnostic tests. This minimizes the train line cable losses.
 - C. Multiple PSCs may be enabled by the HEU if they meet the requirements of Sections 2.3.3.2.2 and 2.3.3.2.2.1. HEU logic in selecting multiple PSCs to enable may be manufacturer specific.
3. If all available PSCs indicate input voltage below the locomotive specific threshold, the HEU may enable one or more PSCs using a manufacturer-specific algorithm. After operating for 15 minutes with PSC(s) indicating low input voltage, the HEU may command the CCDs on the train line to limit their input power to less than 5 W average as defined in Section 2.3.13. The HEU shall warn the engineer of this condition. If a PSC indicates that its input voltage is above the locomotive specific threshold, it shall be enabled, PSCs with low input voltage shall be disabled, and the CCDs shall be commanded back to their normal power input mode.

2.3.3.3.2.1 HEU Multiple PSC Management

When there are multiple PSCs available in a train, the lead HEU shall first attempt to enable the PSC that is located on the lead locomotive as a primary power supply (section 2.3.3.2.1).

If the lead locomotive's PSC cannot be enabled as a primary power supply, the HEU shall inform the engineer of the locomotive road number corresponding to the next available PSC. The HEU shall require the engineer's confirmation that this locomotive is in the train before enabling its PSC as a primary and turning train line power on.

2.3.4 Train brake commands

2.3.4.1 The HEU brake controller shall provide the engineer with a means for making the following braking commands:

- Full brake release
- Graduated brake release
- Minimum service brake application
- Graduated service brake application
- Full-service brake application
- Emergency brake application
- Suppression

2.3.4.2 The train brake commands (TBC) determine the level of brake application for electronically controlled brake systems and shall be expressed as a percentage from 0% to 100% of full-service braking force in 1% increments. A 100% TBC shall be for full service, and 0% shall be for full release. Minimum

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service shall be at 10%, and an emergency brake application (whether intentional or the result of a fault or penalty) shall result in a TBC of 120%. When operating in passenger mode and an emergency application is commanded, the CCDs shall command an emergency service pressure defined in the CCDs' static data.

2.3.4.3 A suppression brake application shall be railroad specific and programmed into the locomotive ID module. The default suppression brake application shall be full service.

2.3.5 Minimum service application

The minimum service brake application shall be at TBC = 10%. The minimum service brake cylinder pressure (MSP) is a preset value programmed in to the car ID module. Minimum service brake cylinder default is 10 psig if no other value is provided in the car ID module.

2.3.5.1 Snow brake application

The snow brake function shall be initiated by the HEU and communicated to the CCDs via the HEU beacon.

When operating in ECP mode, the CCD may implement on an application specific basis the ability to perform snow braking.

When a CCD that supports snow braking is receiving the snow brake command, the brake system shall respond in such fashion to allow for slack adjustment.

If a vehicle receives a TBC greater than zero while a snow brake application is being commanded, then the CCD shall use the larger of the two target pressures.

2.3.6 Full service brake cylinder pressure

2.3.6.1 Loaded full service pressure

The CCD shall have a full-service pressure parameter that is configured for customer specific braking requirements.

2.3.6.2 Empty full service pressure

The CCD may use an empty full-service pressure parameter that is configured for customer-specific braking requirements.

2.3.6.3 Targeted full-service pressure

When operating in ECP mode, the CCD shall target a full-service brake cylinder control pressure based on the load weigh value per Section 2.3.9 below.

2.3.7 Emergency brake cylinder pressure

When the CCD is in ECP passenger mode, the target emergency service pressure shall be configured as a percentage of the targeted full service control pressure.

2.3.8 CCDs determine car load value

Passenger ECP vehicles shall locally perform any required load weigh braking and are not required to report the load weigh status to the HEU. In the absence of load weigh data or when not equipped with a load weigh device, the default brake command will be the fully loaded brake cylinder pressures. If controlled electronically, the load weigh brake cylinder correction shall be mapped linearly to a value between the empty and loaded brake cylinder control pressures defined in the static data.

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2.3.9 Adjustment of BCP to train brake command

2.3.9.1 The brake cylinder pressure curve for TBC vs. BCP is determined based on the Min-Service and the calculated Full-Service and Emergency BCP(s) for a given car weight. The following formulas are used to determine this BCP curve.

Train Brake Command (TBC)	Brake Cylinder Pressure (BCP)
0%	BCP = 0 psi
$0 < TBC \leq 10\%$	BCP = MSP (Min-Service BCP, per Section 2.3.5)
$10 < TBC \leq 100\%$	BCP = $m(x) + b$ where $m = (FSP - MSP) / (100 - 10)$ $b = FSP - m(100)$ $x = TBC$
TBC = 100%	BCP = Full-Service BCP, per Section 2.3.6
TBC > 100%	BCP = Emergency BCP, per Section 2.3.7

2.3.9.2 Other algorithms may be used to derive service BCP on less than fully loaded cars

2.3.10 Brake cylinder pressure control

Vehicles shall control brake cylinder pressures according to the following performance requirements. All timing requirements are measured from the time the vehicle has received the TBC.

1. Steady-state BCP regulation shall be within ± 3 psi of the final commanded target pressure.
2. The BCP control shall be as follows:
 - Minimum service application: BCP shall reach the target pressure, from a full release, within ± 3 psi in no more than 2 seconds.
 - Full-service application: BCP shall reach the target pressure, from a full release within ± 3 psi in no more than 6 seconds nor less than 4 seconds.
 - Emergency service application: BCP shall reach the target pressure, from a full release within ± 3 psi in no more than 3 seconds nor less than 1.5 seconds.
3. Full-service release performance: When commanded to a zero TBC, the BCP shall reduce to less than 5 psi in no more than 7 seconds nor less than 3 seconds.

2.3.11 Mechanical brake cylinder and reservoir venting

NOTE: In order to meet the intent of this section, it is recommended that a passenger vehicle provide a means of cutting out the main reservoir or brake cylinder to allow the pressure to be vented fully by the system.

A method shall be available to manually vent brake cylinder pressure and reservoir pressure at every CCD location from both sides of the car without reliance on electronic activation or electronic control. It shall be possible to vent the brake cylinder pressure independently of the reservoir pressure, but not vice versa.

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NOTE: It is important to recognize that the brakes may still apply on a car that has its dirt collector cutout cock in the closed/isolated position when operating in ECP, and that the reservoirs must also be drained before a maintenance action is initiated.

The following requirements are listed in no particular sequential order:

1. The brake cylinder release valve shall be capable of releasing air pressure from all brake cylinders of air brake equipment regardless of the charge state of the brake pipe.
2. The brake cylinder release valve shall be capable of being manually actuated to release position by a single momentary pull of a release rod, from either side of the car, without requiring that the rod be held until brake cylinder pressure has been depleted.
3. When electrically cut in, a CCD in the brake cylinder venting state shall generate an incorrect brake cylinder exception in accordance with Section 2.4.10.
4. The reservoir air pressure shall be released by holding the release rod in the activated position. When electrically cut in and the reservoir has vented, the CCD shall become inoperable and shall generate a low reservoir exception in accordance with Section 2.4.6.
5. The brake cylinder release valve shall not release brake cylinder pressure during any brake application except under the circumstances of actuation by the release rod.
6. When activated while the brakes are applied, the brake cylinder release valve shall prevent the further flow of air from the reservoir to the brake cylinder.
7. The car's pneumatic backup shall remain functional in accordance with Section 2.3.18 when the brake cylinder release valve has been activated.
8. When the manual release is activated while the brake pipe is charged and the brakes are applied, the following events will occur:
 - Brake cylinder pressure will not reapply if the brake pipe remains charged and TBC remains non-zero.
 - Brake cylinder pressure will reapply when the brake pipe is vented due to pneumatic backup. The brake cylinder release valve shall reset automatically to reestablish the normal operating connection to the brake cylinder once brake pipe pressure has been restored and any of the following occur:
 - Train Brake Command (TBC) = 0%
 - Brake pipe is subsequently vented
 - CCD is shut down and then powered up
 - The engineer reinitializes the train (Section 2.2.3)
 - During RUN mode, the engineer commands the CCD to individually cut in.
9. The brake cylinder release valve shall not permit air to flow from the reservoir to the brake cylinder while resetting.
10. The brake cylinder release valve may automatically reset upon depletion of reservoir pressure by leakage or otherwise but it shall not permit development of brake cylinder pressure sufficient to set all brake shoes against the wheels of the car.

2.3.12 CCD cut out/cut in

When the CCD receives a CUTOUT mode HEU beacon, it shall transition to emulation mode per section 2.2.8.

2.3.12.1 Under certain conditions, a CCD may cut out on its own or be commanded to cut out by the HEU. When a CCD is cut out, it releases its ECP brake application and relinquishes control of brake cylinder pressure to the pneumatic backup. If brake pipe is charged and a pneumatic application is not in effect, brake

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cylinder pressure will release; otherwise it will remain at the level commanded by the pneumatic backup. When cut out, the CCD continues to charge its reservoir. If capable, a cutout CCD will continue to transmit its status to the HEU in response to the polling cycle, however, it will not respond to the brake command. A CCD that reports a status of cut out will be considered inoperative by the HEU. A CCD that is cut out is only polled once per polling cycle by the HEU.

Under certain conditions (including Sections 2.4.2.3 and 2.4.12.1), the HEU may automatically (without engineer action) command individual CCD(s) to cut out. In RUN mode, the HEU shall automatically command CCDs to cut out only if the low percent operable penalty brake application is not active.

2.3.12.2 A CCD shall cut out for the following reasons:

1. HEU commands a single CCD to cut out. This command is initiated by the engineer or the HEU.
2. CCD detects a critical loss and determines that it is isolated.
3. Other CCD faults.
4. CCD detects that its transceiver is generating uncontrolled signal transmissions.
5. CCD detects low battery charge and train line power is not available.
6. CCD detects default or incorrect car static data (reference Section 2.4.12.1)

2.3.12.3 Except when the train operating mode is set to CUTOOUT, when a CCD cuts out, it shall transmit an exception message to the HEU if capable. If the CCD is operating on an over-lay-equipped car without stuck brake protection, a visual and audible warning shall be given to the train engineer any time a CCD is cut out or cuts out for any reason. This warning shall be acknowledged. While cut out, a CCD shall suppress non-critical exception messages except for incorrect BC pressure (due to a BCP stuck brake).

While cut out, a CCD shall continue to monitor its BC pressure. If the CCD detects Incorrect BCP (due to a BCP Stuck Brake; reference Section 2.4.10), the CCD shall generate an Incorrect BCP exception.

2.3.12.4 Once a CCD is cut out, it shall remain cut out until one of the following occurs:

1. HEU commands a single CCD to cut in. This command is initiated by the engineer or the HEU.
2. CCD cuts in if it detects (via HEU beacon) that the operating mode was changed from CUTOOUT to another mode.
3. A CCD with fault detects that the fault condition is cleared. However, the HEU still considers such a CCD as cut out and inoperative until the HEU determines that the CCD is cut in.
4. HEU reinitializes train.

2.3.13 CCD/EOT power system

2.3.13.1 The power on each CCD/EOT shall be maintained through a rechargeable battery system (refer to Standard AAR Standard S-4220, “ECP Cable-Based Brake DC Power Supply—Performance Specification,” latest revision. Batteries are continuously charged from the train line while it is energized via an on-board battery charger. In case of train line power failure and local car battery power, CCDs and EOTs with fully charged batteries shall be capable of operating on battery backup power for at least 4 hours. The battery backup system within a CCD may be configured to allow the device to operate normally from train line power with a fully discharged, failed, or missing battery. A CCD in this condition may be considered as operative for the calculation of percentage operable brakes until the combined total of CCDs in this condition and other

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inoperative CCDs exceeds the penalty brake threshold. Refer to Section 2.4.8, “CCD or EOT Detects Low Battery Charge” for fault response.

2.3.13.2 Power consumed by each battery charger/CCD shall be limited to 50 W peak. The EOT shall be limited to 20 W peak.

2.3.13.3 The passenger ECP system shall have the ability to operate off of the local car power. The local car power shall be used when operating in emulation mode and when trainline power is not available in ECP operation.

2.3.14 Network device input characteristics

The input impedance of any network device shall be nominally 2,000 ohms in the 100 KHz to 450 KHz frequency band in receive mode.

2.3.15 Network device output characteristics

Output conducted emissions on the train line shall generally meet the requirements of FCC Section 15.107. Specifically, the conducted emissions as measured on the train line in differential mode may not exceed 106 dB μ V from 9 kHz to 40 kHz; 86 dB μ V from 40 kHz to 125 kHz; 36 dB μ V from 125 kHz to 140 kHz; 56 dB μ V from 140 kHz to 450 kHz; and 48 dB μ V from 450 kHz to 30 MHz.

2.3.16 CCD or EOT in shutdown mode

Shutdown mode (or “battery conservation” mode) shuts off the EOT to minimize battery drain. When shut down, the EOT is turned off. When a CCD shuts down, it releases its ECP brake application and relinquishes control of brake cylinder pressure to the pneumatic backup. If the brake pipe is charged and a pneumatic application is not in effect, brake cylinder pressure will release; otherwise it will remain at the level commanded by the pneumatic backup. When an EOT shuts down, it stops transmitting EOT beacons. Once train line power is lost, the CCD or EOT either continues to operate off of battery power until its battery runs low or enters into a timed shutdown mode. The intent of this logic is to allow the train to operate as long as possible after a loss of train line power and to conserve batteries if the device is disconnected from the train line, the train is parked, or the ECP brake system is CUTOFF.

- The EOT shall remain in a timed shutdown process while both train line power and HEU beacons are not present.
- If brake pipe pressure is less than 5 psi, the EOT shall shut down in 2 minutes; otherwise, the EOT shall shut down in 1 hour.
- The EOT shall shut down immediately after the train line power is lost and the train operating mode is set to CUTOFF.

When the CCD ends ECP mode, it shall transition to emulation. If trainline power and local power are lost, the CCD shall operate off of the backup battery until the backup battery runs low.

2.3.17 Messaging requirements

These requirements are covered in detail in AAR Standard S-4230, “Intratrains Communication Specification for Cable-Based Freight Train Control Systems,” latest revision. The following Sections are intended to give a brief description.

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2.3.17.1 HEU Beacon

The HEU beacon shall be a priority message broadcast by the HEU once per second (1.0 Hz) and shall contain a unique identifier, train brake command (TBC), and a network device status query, among other information, as described in AAR Standard S-4230, “Intratraining Communication Specification for Cable-Based Freight Train Control Systems,” latest revision.

2.3.17.1.1 Train Brake Commands

A TBC shall be broadcast as part of the HEU beacon and shall be a percentage of full-service braking force: 0% shall be full release; 10% shall be minimum service application; 11% to 99% shall be graduated service; 100% shall be full service; and 120% shall be emergency braking.

2.3.17.1.2 Network Device Status Query

Each HEU beacon shall include a status query for an individual network device (trail HEU, PSC, or CCD) during RUN mode. The network device status query shall be used by the ECP brake system to periodically verify communications and control between the HEU and all network devices on the train. It also shall gather data for diagnostic and event recording purposes. Network devices shall be queried for their operating status on a round-robin basis by the HEU. During each round-robin cycle, all CCDs, all active PSCs, and at least one inactive device (trail HEUs and standby PSCs) shall be queried. Status queries to all inactive devices shall be completed on successive round-robin polling cycles. With the transmission of each HEU beacon once per second, the HEU will query a different network device by transmitting its address and a request for its status.

2.3.17.2 Train Configuration Command

Once every 120 seconds and upon setup changes, the HEU shall broadcast a configuration command message. This message shall contain the current BPP setpoint, and other information as defined in AAR Standard S-4230, latest revision.

2.3.17.3 CCD Status Messages

When a CCD is queried, it shall transmit the following information:

1. Brake pipe pressure
2. Percentage brake applied (BCP relative to full-service application)
3. Reservoir pressure
4. Cut-in/cutout status
5. Other information as identified in AAR Standard S-4230, “Intratraining Communication Specification for Cable-Based Freight Train Control Systems,” latest revision.
6. Brake cylinder pressure
7. Battery percentage charged
 - a. To be sent as a value in the range of 0% to 100% in 10% increments
 - b. 20% or less shall be defined as a low battery
 - c. 100% shall be defined as a fully charged battery
8. Train Line Power Status (ON/OFF). The CCD shall report a Train Line Power Status of ON when it is powered from the train line; otherwise it shall report a Train Line Power Status of OFF.

Some of this information may be recorded by the locomotive’s event recorder and/or made available for display to the engineer. To give “percent brake applied” status, the CCD shall compute the percentage of full-service BCP applied during each status query.

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NOTE: EOT brake pipe pressure is not required to be valid.

2.3.17.3.1 Train Brake Effort (TBE)

When in RUN mode, the percentage brake applied reported by the CCDs is used to determine the Train Braking Effort (TBE).

Train Braking Effort (TBE) is a determination by the Lead HEU of the combined braking effort of all of the CCDs in the train for the purpose of providing feedback to the train operator. This determination takes into account CCDs that are cut in, cut out, or not responding. The TBE for cut-out cars is tracked separately from the cut-in cars, and then the final TBE is determined based on the following formula:

$$\text{TBE Train} = \frac{(\# \text{ of cut-in CCDs} \times \text{TBE cut in}) + (\# \text{ of cut-out CCDs} \times \text{TBE cut out})}{\text{Total \# CCDs}}$$

Where

TBE cut in = a weighted average of the previous TBE cut in and the percentage brake applied of the last cut-in CCD polled

TBE cut out = a weighted average of the previous TBE cut out and the percentage brake applied of the last cut-out CCD polled

Last CCD polled is weighted twice as much as the previously calculated TBE.

This is expressed with the following formula:

$$\text{TBE cut in} = \frac{\text{TBE cut in} + (2 \times \text{PBA}_{\text{Last cut-in CCD polled}})}{3}$$

$$\text{TBE cut out} = \frac{\text{TBE cut out} + (2 \times \text{PBA}_{\text{Last cut-out CCD polled}})}{3}$$

Where

PBA= percentage brake applied as reported by the CCD

CCDs reporting a Percentage Brake Applied of Unknown or not responding to the poll are not included in the calculation of TBE Cut in or TBE Cut out, but are included in the overall TBE calculation based on the # of CCDs cut in and # of CCDs cut out. A CCD that does not respond to a poll is considered cut out.

The TBE shall be displayed on the lead locomotive with a resolution of 1%.

2.3.17.4 EOT Beacon/Status Message

The EOT beacon shall be a priority message transmitted to the HEU once per second (1.0 Hz) and shall contain a status message that includes the brake pipe pressure, percentage of full battery charge, train line voltage, and other information as identified in AAR Standard S-4230, "Intratrains Communication Specification for Cable-Based Freight Train Control Systems," latest revision. This information may be recorded by the locomotive's event recorder and/or made available for display to the engineer. The brake pipe pressure at the EOT may be displayed if provided continuously to the engineer via the HEU.

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2.3.17.5 PSC Status Message

When a PSC is queried, it shall read and transmit the following quantities:

1. Status data
2. Train Line voltage
3. Other information as identified in AAR Standard S-4230, “Intratrain Communication Specification for Cable-Based Freight Train Control Systems,” latest revision
4. Input voltage
5. Output current

Some of this information may be recorded by the locomotive’s event recorder and/or made available for display to the engineer.

2.3.17.6 Trailing HEU Status Message

When a trailing HEU is queried, it shall read and transmit the following quantities:

1. Status data
2. Other information as identified in AAR Standard S-4230, “Intratrain Communication Specification for Cable-Based Freight Train Control Systems,” latest revision

Some of this information may be recorded by the locomotive’s event recorder and/or made available for display to the engineer.

2.3.17.7 Exception Messages

A network device shall generate an exception message when and as required by Section 2.4 of this document and by AAR Standard S-4230, “Intratrain Communication Specification for Cable-Based Freight Train Control Systems,” latest revision.

2.3.17.8 Control Messages

Control messages are generated by the HEU to command CCDs, PSCs, or EOT to operate in certain ways. They include the following:

- CCD cut-in/cutout
- Operating mode
- Train initialization and sequencing
- PSC enabled/disabled
- Version compatibility

(Other messages concerning car health monitoring and distributed locomotive control are covered by AAR Standard S-4230, “Intratrain Communication Specification for Cable-Based Freight Train Control Systems,” latest revision.)

2.3.18 Pneumatic backup

2.3.18.1 Each car shall have a means of propagating a pneumatic emergency and of pneumatically applying emergency brake cylinder pressure (i.e., requiring no electrical power). The pneumatic backup system shall

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al-ways be capable of providing emergency brake cylinder pressure (assuming reservoirs are adequately charged) in the event of a pneumatic emergency whether or not the CCD is operational.

2.3.18.2 The pneumatic backup (PB) system shall include an AAR-approved (or equivalent) pneumatically controlled brake pipe emergency venting device that shall be required on all

ECP-equipped cars, whether a “pure” ECP or an overlay system is used. Said emergency venting device(s) shall always be active (enabled) when connected to the brake pipe; however, they shall not undesirably vent BPP in response to typical service fluctuations of BPP, either when the ECP is operational or during pneumatic operation in an overlay system. The pneumatic backup equipment shall conform to existing AAR specifications for emergency venting devices as follows:

- Spacing in accordance with the Section entitled “Additional Equipment for Cars with Brake Pipe Length in Excess of 75 ft” in AAR Standard S-401, “Freight Car Brake Design Requirements.” (Note: the words “control valve” refer to the emergency venting device for ECP operation.)
- Triggering (by the rapid venting of BP to zero) compliant with the Section entitled “Emergency Test,” in AAR Standard S-486, “Code of Air Brake System Tests for Freight Equipment—Single Car Test.”

2.3.18.3 When possible, electronic CCD operation shall take precedence over or assist the pneumatic backup in controlling BCP. Operating CCDs shall sense loss of BPP (see Section 2.4.3.3) and respond accordingly. CCDs that may not be able to completely take precedence over pneumatic backup (e.g., overlay CCDs, CCDs not communicating with the HEU but still powered by the train line) shall assist in controlling BCP to the emergency pressure appropriate to car loading (see Section 2.3.8).

2.3.18.4 The pneumatic backup must remain active when a CCD has been cut out, disabled, or shut down or has stopped receiving the HEU beacon. A pneumatic emergency brake application shall be released when the brake pipe pressure has increased between the initial application threshold and the remaining reservoir pressure or when electronic CCD operation has taken precedence.

NOTE: Cars at any load not equipped with a pneumatic empty/load device will apply emergency brakes at the loaded car pressure when the pneumatic backup applies the brakes.

2.3.18.5 Pneumatic Backup Brake Performance

2.3.18.5.1 The pneumatic backup (PB) application shall always be available irrespective of the existing state of ECP operation, providing no mechanical isolation of the brake pipe signal by means of dirt collector cutout cocks has been established.

2.3.18.5.2 The pneumatic backup signal transmission rate shall exceed 750 ft/sec on an AAR standard 150-car test rack.

2.3.18.5.3 The pneumatic backup brake cylinder build-up time shall meet the requirements of an ECP emergency application and shall be no more than 12 seconds nor less than 7 seconds

2.3.18.5.4 With any group of five consecutive PB-equipped, 50-ft cars pneumatically cut out, an emergency reduction of brake pipe pressure shall cause the remainder of the PB-equipped cars to operate in emergency.

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2.3.19 Continuous reservoir charging

The car brake system supply reservoir shall be charged continuously from either the brake pipe or the main reservoir. The brake pipe is not the primary mode of charge and is used as a backup. Airflow from the main reservoir or brake pipe to the supply reservoir shall never be interrupted; however, a mechanism shall be provided to prevent reversal of flow from the supply reservoir to the main reservoir or brake pipe.

2.3.19.1 Control valve charging shall be an equivalent size so that an AAR standard 6,000-in.³ reservoir will reach 85 psi in 410 to 480 seconds when charged from a 90-psi brake pipe pressure.

2.3.20 Other equipment operating as an EOT

NOTE: In passenger ECP systems, the capability to read the BPP is not required for a locomotive, cab car, or ECP vehicle.

2.3.20.1 The ECP equipment on the last ECP vehicle in the train, if it is also the last vehicle in the train, may perform the functions of the EOT as defined in this document and in AAR Standard S-4230, “Intratrain Communication Specification for Cable-Based Freight Train Control Systems,” latest revision.

2.3.20.2 The ECP equipment on a locomotive shall automatically enable the EOT function if the following conditions are met:

1. The last vehicle ECP equipment is capable of measuring train line voltage.
2. The last vehicle ECP equipment detects the presence of the train line termination.
3. The last vehicle ECP equipment is not on the lead locomotive.
4. The last vehicle ECP equipment is receiving HEU beacons.
5. The last vehicle ECP equipment is not receiving EOT beacons.

2.3.20.3 Once the EOT function has been enabled for an ECP device, that device shall continue to perform the EOT function until one of the following conditions is met:

1. Train line power is lost and no HEU beacons are detected for more than 1 hour.

2. Train line power is lost and the train operating mode is set to CUTOUT.
3. EOT beacons from another ECP network device, an EOT, or another ECP device are detected on the train line.

2.3.20.4 The purpose of the requirements in this section is to support a train that is operating with the last vehicle in the train is a locomotive, cab car, or ECP vehicle. To provide locomotive brake control for critical loss penalties, the last vehicle functioning as the EOT shall be capable of detecting an ECP critical loss and providing local brake cylinder control.

2.3.20.5 ECP equipment functioning as the EOT shall perform the normal EOT fault response and recovery as specified in Sections 2.3.20.6 and 2.4.

2.3.20.6 Locomotive, Cab Car, or ECP vehicle as ECP EOT Loses Train Line Termination

If the last vehicle ECP equipment functioning as the EOT detects the removal or loss of its train line termination, it shall stop transmitting EOT beacons

2.3.21 Cab car functionality

2.3.21.1 Cab car as a CCD

The cab car shall always support the requirements of a passenger CCD and be counted as an operable brake with the following exception:

1. If the battery percentage is not available, the cab car shall report a 100 percent battery charge percentage.

2.3.21.2 Cab car as an HEU

When operating as lead HEU, the cab car shall perform the functions of a lead HEU. When operating as a trailing device, the cab car shall not respond as a trailing locomotive.

2.4 Fault response and recovery functions

The following fault modes (response functions) apply to both pure ECP and overlay operation. All fault-induced brake applications must remain in effect for 120 seconds or until the train has stopped before recovery procedures (see Section 2.4.16) can be initiated. Operating mode changes can be made only after the train is stopped or after the 120-second timer has expired (see Section 2.2.2.1).

When a CCD, PSC, or EOT (including locomotive ECP equipment functioning as an EOT) experiences multiple faults, only the most serious fault shall initially be reported and acted upon. Only when this fault is cleared shall the lower priority faults be acted upon. The hierarchy of fault severity shall be as shown in **Table 2.2**.

The HEU, upon receiving CCD, PSC, Trailing HEU, or EOT exception messages and/or generating its own exceptions, shall prioritize them as shown in **Table 2.3**. When the HEU detects a fault condition, the highest priority condition is acted upon first. Lower priority faults are handled only after high-priority faults are cleared.

When an emergency brake application is active, a CCD shall suppress all exception messages except for Critical Loss exception messages. Recovery from an emergency brake application shall cause all CCD, trailing HEU, and EOT fault logic to be reset and/or enabled.

Exception-Clear messages shall be allowed when the HEU is commanding an emergency. Exception messages from a PSC shall be allowed in any mode.

Note that unless the ECP EOT brake pipe pressure is known, the exceptions related to low brake pipe and loss of brake pipe pressure from the EOT will not apply.

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TABLE 2.2
 CCD, PSC and EOT Fault Hierarchy and Exception Priority

Fault-Degree	Type of Fault	Fault
1	Fault that may immediately disable the entire ECP control network	<ul style="list-style-type: none"> • CCD/EOT/PSC Transceiver Generates Uncontrolled Signal Transmission
2	Fault that may cause a penalty or emergency brake application	<ul style="list-style-type: none"> • CCD/EOT Detects Critical System Loss • PSC Detects Multiple HEUs • EOT Detects Low Battery Charge
3	Fault that may cause system degradation	<ul style="list-style-type: none"> • EOT Detects Low BPP • PSC Detects Loss of HEU Beacon • EOT or PSC Detects Low/High Train Line Voltage • PSC Detects Train Line Short Circuit • PSC Detects Low Input Voltage • PSC Detects Enable Fault
4	Fault that may disable a single CCD, PSC, or EOT	<ul style="list-style-type: none"> • CCD Detects Incorrect BC Pressure • CCD Detects Low Reservoir Pressure • CCD Detects Low Battery Charge • CCD, PSC, or EOT Detects Other Manufacturer-Specific Self-Diagnostic Fault • CCD Detects a Car ID Fault

TABLE 2.3
 HEU Fault Hierarchy and Exception Priority

Fault Degree	Type of Fault	Fault
1	Fault that may immediately disable the entire ECP control network	<ul style="list-style-type: none"> • HEU Transceiver Generates Uncontrolled Signal Transmission
2	Fault that requires an emergency brake application	<ul style="list-style-type: none"> • Two CCD/EOTs Report Critical Loss within 5 seconds • HEU Misses EOT Beacon when in RUN mode • Crew Commands an Emergency Brake Application
3	Fault that requires a full-service brake application.	<ul style="list-style-type: none"> • <50% Operative Brakes Detected • EOT Reports Low Battery Charge • Penalty Brake Application • EOT Reports Critical Loss • PSC Reports Detection of Multiple Lead HEUs
4	Fault that indicate multiple brakes may eventually be disabled.	<ul style="list-style-type: none"> • <85% Operative Brakes Detected • <75% Operative Brakes Detected • CCD Reports Low Reservoir Pressure • CCD Goes Off Line (or Cuts Out) • CCD Reports Low Battery Charge • EOT or PSC Reports Low or High Train Line Voltage • EOT Reports Low Brake Pipe Pressure • PSC Reports Other Disabling Fault
5	Individual device faults	<ul style="list-style-type: none"> • CCD Detects Incorrect BC Pressure • PSC or Trail HEU Fails to Respond to Status Query • CCD/EOT/PSC/trail HEU Detects Other Self-Diagnostic Fault

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2.4.1 System fault-initiated brake applications

2.4.1.1 Conditions causing fault-initiated emergency (as differentiated from penalty and intentional) application are described in the following Sections:

- HEU transceiver generates uncontrolled signal transmission (see Section 2.4.2.7)
- HEU misses EOT beacon when in RUN mode (see Section 2.4.2.1)
- HEU receives at least two Critical Loss exception messages from CCDs or EOT (see Section 2.4.4.3)
- CCDs may self-initiate an emergency brake application in response to multiple CCDs and/or EOT detecting a critical loss (see Section 2.4.4.1)

2.4.1.2 Conditions causing a fault initiated full-service application are described in the following Sections:

- HEU registers less than 50% operative brakes (see Section 2.4.5.2)
- EOT low battery charge (see Section 2.4.8)

2.4.1.3 Conditions causing a penalty full-service brake application are described in the following Sections:

- HEU receives “Critical Loss” message from EOT (see Section 2.4.4.5)
- PSC reports detection of multiple lead HEUs (see Section 2.4.11)

2.4.2 Signal transmission faults

2.4.2.1 HEU misses EOT beacon (RUN Mode only)

If the HEU fails to receive the EOT beacon for 6 seconds, the engineer shall be given an audible and visible warning and the HEU shall automatically command an emergency brake (TBC=120%) command and transmit a “train line power-off” command (see Section 2.3.3.1.2).

2.4.2.1.1 Recovering from a missed EOT beacon fault

2.4.2.1.1.1 If an HEU in this fault condition subsequently receives the EOT beacon, the fault is cleared and the HEU will enable system recovery as described in Section 2.4.13. Loss of the EOT beacon for more than 15 seconds while in RUN mode shall require a re-initialization of the train.

2.4.2.1.1.2 If the EOT beacon cannot be restored, then the engineer may change mode.

2.4.2.2 Failure to receive HEU beacon

2.4.2.2.1 CCD or EOT or trailing HEU misses HEU beacon

If any CCD, trailing HEU, or EOT fails to receive the HEU beacon for 6 seconds, then the CCD or trailing HEU shall maintain the current brake application and the CCD, trailing HEU, or EOT shall broadcast a Critical Loss exception message (see Section 2.4.4).

2.4.2.2.1.1 Last ECP vehicle EOT function loses HEU beacon

If the ECP equipment functioning as the EOT fails to receive the HEU beacon for 6 seconds, then the ECP equipment shall stop transmitting EOT beacons, transmit a Critical Loss exception message, and make an electronic emergency brake application (see Section 2.3.1.5).

2.4.2.2.2 Clearing a CCD or EOT or trailing HEU misses HEU beacon exception

If a CCD or EOT or trailing HEU subsequently receives the HEU beacon, it shall clear this exception, but shall not transmit an Exception-Clear message. If the TBC in the HEU beacon is less than 120%, all other

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critical exception logic shall also be reset. After communication with the HEU is restored, and the CCD or EOT or trailing HEU has no other faults, it shall resume normal operation.

2.4.2.3 HEU does not receive CCD's response to status query (RUN Mode only)

If the HEU does not receive a response from a CCD logged as cut in to a Status Query message, the HEU shall repeat the status query (re-poll the CCD) up to two times. If the HEU does not receive the CCD's response by the third query, the CCD is logged as inoperative by the HEU, and the HEU transmits a cutout command to the CCD in accordance with Section 2.3.12.1.

2.4.2.3.1 Recovery of a CCD that failed to respond to status query

If a CCD that is cut out because it failed to respond to the HEU status query responds to subsequent HEU status queries and reports that it is cut-in, the HEU shall log this CCD as operative.

2.4.2.4 HEU does not receive PSC's response to status query

2.4.2.4.1 If the HEU does not receive a response from a PSC to a Status Query message, the HEU shall repeat the status query (re-poll the PSC) up to two times. If the HEU does not receive the PSC's response by the third query and it is an active PSC, the PSC shall be commanded to an inactive state and another PSC shall be commanded to an active state (if available) to power the train line.

2.4.2.4.2 If the HEU does not receive the PSC's response by the third query and it is an inactive PSC, the HEU shall log the PSC as inoperative for the purpose of being available for activation.

2.4.2.4.3 If the PSC later resumes responding to the status query and has no other faults, the HEU shall log the PSC as available for activation.

2.4.2.5 HEU does not receive trailing HEU's response to status query

2.4.2.5.1 If the HEU does not receive a response from a trailing HEU to a Status Query message, the lead HEU shall repeat the status query (re-poll the trailing HEU) up to two times. If the lead HEU does not receive the trailing HEU's response by the third query, the lead HEU shall log that trailing HEU as inoperative.

2.4.2.5.2 If the trailing HEU later resumes responding to the status query and has no other faults, the lead HEU shall log the trailing HEU as operative.

2.4.2.6 PSC misses HEU beacon

If a PSC fails to receive the HEU beacon for 6 seconds, it shall automatically de-energize its train line power output and enter a disabled state. A PSC shall not broadcast a Critical Loss exception.

2.4.2.6.1 Clearing PSC misses HEU beacon exception

If a PSC subsequently receives the HEU beacon and the PSC has no other faults, it shall respond to subsequent status queries that it is available for activation.

2.4.2.7 Network device's transceiver generates uncontrolled signal transmissions

A means shall be provided within each network device on the train line network to detect if it is transmitting improper signals or noise onto the communications network and to disable its transmitter within 1 second. This method shall detect the presence of improper signals and ascertain that the local transceiver is the source. It shall then interrupt the transceiver by commanding an immediate shutdown of the transceiver.

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The device with the faulty transceiver shall cut out and shut down its transmitter within 1 second. The device may attempt to re-enable its transmitter a maximum of two times, with a minimum retry interval of 30 seconds, before shutting it down permanently. (Removal and reapplication of power shall allow the device to re-enable its transmitter subject to another shutdown if uncontrolled signal transmissions are detected.)

2.4.2.7.1 HEU transceiver generates uncontrolled signal transmissions

If the HEU's transceiver is the source of the fault, the HEU shall shut off its transmitter and, if it is the LEAD HEU, it shall then warn the engineer.

2.4.2.7.2 PSC transceiver generates uncontrolled signal transmissions

If an enabled PSC's transceiver is the source of the fault, the PSC shall shut off its transmitter, disable its train line power output, and enter an inactive state.

2.4.2.7.3 CCD transceiver generates uncontrolled signal transmissions

If a CCD's transceiver is the source of the fault, the CCD shall shut off its transmitter and cut out.

2.4.2.7.4 EOT transceiver generates uncontrolled signal transmissions

If an EOT's transceiver is the source of the fault, the EOT shall shut down its transmitter. Normal HEU fault logic shall then respond accordingly to the loss of EOT beacon.

2.4.2.7.5 Recovery procedure for uncontrolled signal transmission

The faulty device must be cut out or otherwise disconnected from the network. In the case of the HEU, another locomotive must be used as lead locomotive or the HEU must be replaced. In the case of the EOT, the EOT must be replaced or the system mode must be changed.

2.4.3 Low brake pipe pressure (BPP); only if known to be accurate

2.4.3.1 EOT detects low BPP; only if BPP is known to be accurate

If an EOT detects BPP less than $(0.67 \times \text{BPP setpoint})$, it shall transmit a Low BPP exception message to the HEU.

2.4.3.1.1 HEU response to EOT Low BPP; only if BPP is known to be accurate

The HEU shall detect low BPP at the EOT. On detection of low BPP at the EOT, the HEU shall give an audible and visual warning to the engineer. The HEU may detect low EOT BPP either by receipt of an EOT Low BPP exception message or based on information transmitted in the EOT beacon.

2.4.3.2 EOT detects loss of BPP; only if BPP is known to be accurate

If the EOT detects BPP less than $(0.56 \times \text{BPP setpoint})$, it shall broadcast a Critical Loss exception.

2.4.3.2.1 Clearing an EOT low/loss of brake pipe pressure exception; only if BPP is known to be accurate

The Low BPP exception and/or Loss of BPP exception shall be cleared when the EOT detects that BPP rises above $(0.74 \times \text{BPP setpoint})$. When the Low BP exception is cleared, the EOT shall transmit an EOT Low BPP Exception Cleared message to the HEU. When the Loss of BPP exception is cleared, the EOT shall transmit an EOT Loss of BPP Exception Cleared message to the HEU.

2.4.3.3 CCD or trailing HEU detects loss of BPP

Except when in a "no air" condition, if a CCD or trailing HEU detects a loss of BPP, it shall broadcast a Critical Loss exception message. Loss of BPP shall be defined as BPP less than $(0.56 \times \text{BPP setpoint})$. A "no

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air” condition shall be defined as brake pipe pressure, reservoir pressure, and brake cylinder pressure all less than 5 psi, which is normally associated with manual venting of reservoir and brake cylinder pressure.

2.4.3.3.1 Clearing CCD or trailing HEU loss of BPP exception

This exception shall be cleared when the CCD or trailing HEU detects that the BPP rises above ($0.67 \times$ BPP set-point). When this exception is cleared, it shall not transmit a Loss of BPP Exception Cleared message to the HEU.

2.4.3.4 HEU recovery from loss of brake pipe pressure

The HEU shall not allow recovery from a loss of brake pipe pressure as described in Section 2.4.4.6 until it detects that the loss of BPP condition is cleared at the EOT.

2.4.4 System Critical Loss

A System Critical Loss is defined as a loss of HEU beacon or a loss of BPP.

Critical loss fault logic brake control specified in this section for trailing HEUs applies to ECP-equipped locomotives with the ability to provide locomotive retardation based on ECP brake applications as specified in Section 2.3.1.5.

2.4.4.1 Multiple CCDs, trailing HEUs, or EOT has Critical Loss

If a CCD or trailing HEU receives a Critical Loss exception within 5 seconds of experiencing a critical loss, or experiences a critical loss within 5 seconds of receiving a Critical Loss exception message, or receives Critical Loss exception messages from two other devices (CCDs or EOT or trailing HEU) within 5 seconds, then that CCD or trailing HEU, if applicable (see Section 2.3.1.5), shall make an electronic emergency brake application.

CCDs or trailing HEUs that go into self-initiated emergency shall maintain their emergency application, regard-less of the TBC in the HEU beacon, until the System Critical Loss fault condition is cleared as described in Section 2.4.4.6.

2.4.4.1.1 Critical Loss Relay

If the HEU beacon is still being received, CCDs or trailing HEUs that go into self-initiated emergency shall monitor the TBC in the HEU beacon for a period of 60 seconds \pm 10 seconds after it went into self-initiated emergency to ensure that the “critical loss” is propagated to the HEU.

If the TBC in the HEU beacon is not 120% within 5 seconds of self-initiating an emergency, the CCD or trailing HEU shall broadcast a Critical Loss Relay exception. This process shall repeat every 5 seconds until the TBC in the HEU beacon is 120%, the 60-second monitoring period ends, or the CCD and trailing HEU critical loss fault logic is reset by the lead HEU.

The unique IDs of the first two devices generating a critical loss message shall be included in the Critical Loss relay message.

2.4.4.1.1.1 HEU receives Critical Loss Relay message

If the HEU receives one or more Critical Loss Relay exception messages, it shall command an electronic emergency brake application (TBC=120%) and provide a warning to the engineer.

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2.4.4.1.1.2 CCD or trailing HEU receives Critical Loss Relay message

If a CCD or trailing HEU receives a Critical Loss Relay exception, then that CCD or trailing HEU shall make an electronic emergency brake application.

CCDs and trailing HEUs that go into self-initiated emergency shall maintain their emergency application, regardless of the TBC in the HEU beacon, until the System Critical Loss fault condition is cleared as described in Sections 2.4.4.6 and 2.4.4.6.1.

2.4.4.2 Isolated Critical Loss

If a CCD detects a critical loss (loss of HEU beacon or loss of BPP) and does not receive a Critical Loss exception message from any other device within 5 seconds, it will assume the fault is local to the CCD and shall cut out as described in Section 2.3.12.

2.4.4.3 HEU receives at least two Critical Loss messages

If the HEU receives Critical Loss exception messages from two or more devices (CCDs or EOT or trailing HEU) within 5 seconds, then it shall command an electronic emergency brake application (TBC=120%) and provide a warning to the engineer.

2.4.4.4 HEU receives a single CCD Critical Loss message

If the HEU receives only one Critical Loss exception message (loss of HEU beacon or loss of BPP) within a 5-second time period and it is from a CCD, then the HEU shall command that CCD to cut out (see Section 2.3.12).

2.4.4.5 HEU detects EOT Critical Loss message

The HEU shall detect an EOT critical loss. On detection of an EOT critical loss, the HEU shall command a full service brake application and provide a warning to the engineer. The HEU may detect an EOT critical loss either by receipt of a single Critical Loss exception from an EOT or based on information in the EOT beacon.

2.4.4.6 Recovery from system critical fault

After the HEU has detected that the cause of the fault has been eliminated (as described in Sections 2.4.2.1.1, 2.4.2.2.2, 2.4.3.4 and 2.4.3.5), the HEU shall command the system to reset fault processing and allow recovery as described in Section 2.4.13.

2.4.4.6.1 Clearing a CCD or trailing HEU system critical fault

CCDs and trailing HEUs shall reset their critical fault logic on detection of an HEU-commanded critical fault reset, transition out of INIT mode, receipt of the HEU beacon with a TBC less than 120% after an HEU beacon loss event, or on the detection of a transition in the train brake command from 120% to less than 120%.

2.4.5 Reduced percentage of operative brakes

In RUN mode, the HEU shall register as inoperative any CCD that is disabled for any of the following reasons:

- Communication lost (CCD status query not answered)
- Low battery charge with no external power
- Low reservoir charge

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- CCD is cut out
- CCD cannot obtain a BCP of at least 5 psig after minimum service or greater is commanded (BCP cannot apply)

The HEU shall then compute the percentage of operative brakes based on the total number of potentially operative brakes determined during initialization and the number of remaining operative brakes. Fractional percentage operative computation results shall always be truncated down to the next whole percentage point.

CCDs that have a low or missing battery but are functional when external power is active shall be considered operative by the HEU for the purpose of calculating percentage of operative brakes as long as the combined total of these and other inoperative CCDs does not exceed the threshold that causes the HEU to command a penalty full-service brake application.

The following fault responses shall occur if the percentage of operative brakes falls below certain thresholds.

2.4.5.1 HEU registers less than 95%, 90%, 85% and 75% operative brakes (RUN Mode only)

If the percentage of operative brakes falls below 95%, the engineer shall be audibly and visually warned and given the current percentage operable. If the percentage falls below 90%, the engineer shall likewise be warned and given the percentage. These warnings must be acknowledged by the engineer.

Warnings shall also be provided at 85 percent and 75 percent operable (as per CFR 238.15).

2.4.5.2 HEU registers less than 50% operative brakes (RUN Mode only)

If the percentage of operative brakes falls below 50%, the engineer shall be given a warning and the HEU shall command an electronic full-service brake application.

2.4.6 CCD low car reservoir charge

If a CCD detects that its reservoir charge is less than $(0.63 \times \text{BPP setpoint})$, then it will transmit a Low Reservoir Charge exception message to the HEU.

2.4.6.1 Clearing the CCD low car reservoir charge exception

When the CCD detects that its reservoir charge exceeds $(0.74 \times \text{BPP setpoint})$ the fault is cleared and the CCD transmits a Low Reservoir Charge Exception Cleared message to the HEU.

2.4.6.2 HEU receives CCD low reservoir charge message (RUN Mode only)

When the HEU receives a CCD Low Reservoir Charge exception message, it shall record the occurrence and log the CCD as inoperative.

2.4.6.3 HEU receives CCD low car reservoir charge exception cleared message

When the HEU receives a CCD Low Reservoir Charge Exception Cleared message from a CCD, it shall record the occurrence and log the CCD as operative.

2.4.7 Low train line voltage

When the train line voltage falls below 100 Vdc $\pm 4\%$, the ECP brake system shall continue to operate, on battery power if necessary, as defined in Section 2.3.13.

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2.4.7.1 EOT or PSC detects low train line voltage

If, after allowing a 45-second settling period after the HEU beacon power flag is set to ON, the EOT or any PSC detects that train line voltage is below 100 Vdc \pm 4%, it shall transmit a Low Train Line Voltage exception message to the HEU.

2.4.7.2 Clearing an EOT or PSC detects low train line voltage exception

When the EOT or PSC that reported low train line voltage detects that the train line voltage increases to more than 110 Vdc \pm 4%, it shall clear this exception and transmit a Low Train Line Voltage Exception Cleared message to the HEU.

2.4.7.3 HEU receives low train line voltage exception message

The HEU shall provide an audible and visual warning to the engineer that an EOT or PSC detected that the train line voltage is less than 100 Vdc only when train line power is activated. The audible warning shall cease when the engineer acknowledges the warning.

2.4.7.4 HEU receives low train line voltage exception clear message

When all Low Train Line Voltage Exceptions have been cleared, the visual warning shall be removed.

2.4.8 CCD or EOT detects low battery charge

If a CCD or EOT detects low battery charge with train line power off, it shall transmit a Low Battery exception message to the HEU at least 5 minutes before commencing an orderly shutdown as described in Section 2.3.16. With train line power available, a CCD or EOT shall transmit a Low Battery exception message if it detects that its battery would be incapable of powering the device in the event of a loss of train line power. A CCD may continue to operate from train line power if its batteries are unable to power it.

The CCD low battery charge threshold shall correspond to a Battery Percentage Charged level of 20%.

2.4.8.1 Clearing the CCD or EOT low battery charge exception message

When the CCD or EOT with a low battery charge fault detects that its battery has recharged to a sufficient level, it shall transmit a Low Battery Charge Exception Cleared message to the HEU.

The CCD low battery charge clear threshold shall correspond to a Battery Percentage Charged level of 30%.

2.4.8.2 HEU receives CCD low battery charge exception message

The HEU shall include CCDs reporting low battery charge in its calculation of inoperative CCDs.

2.4.8.3 HEU receives CCD low battery charge exception cleared message

The HEU shall include the CCD that cleared the Low Battery exception as an operative brake unless another fault prevents this.

2.4.8.4 HEU detects EOT low battery charge

The HEU shall detect an EOT low battery charge. On detection of an EOT low battery charge, the HEU shall command a full-service brake application and provide a warning to the engineer. The HEU shall detect an EOT low battery charge based on information in the EOT beacon.

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2.4.8.4.1 HEU receives EOT low battery charge exception cleared message

The HEU clears the fault when an EOT Low Battery Charge Exception Clear message is received, the EOT beacon indicates charged battery, or the train mode is changed.

2.4.9 PSC or EOT detects greater than 30 V when power is off

Allowing for a 10-second settling period after the HEU beacon power flag is set to OFF, if the train line voltage monitored by a PSC or the EOT is greater than 30 Vdc $\pm 4\%$, the PSC or EOT shall transmit a High Train Line Voltage exception message to the HEU.

2.4.9.1 Clearing PSC or EOT detects greater than 30 V when power is off

If the train line voltage detected by the PSC or EOT with an active High Train Line Voltage exception is less than 10 Vdc $\pm 4\%$ or the HEU beacon power flag is set to ON, the PSCs or EOT shall transmit a High Train Line Voltage Exception Cleared message to the HEU.

2.4.9.2 HEU receives PSC or EOT detects greater than 30 V when power is off Exception

If the HEU receives a High Train Line Voltage exception message from a PSC or EOT, it shall visually and audibly warn the engineer that the train line voltage is not off. This shall be an acknowledged warning. An indication that the train line voltage is still on shall remain displayed until the PSCs and/or EOT indicate train line power is off.

2.4.10 CCD detects incorrect BCP pressure or stuck brake

If a CCD determines that it is unable to control the BCP for any of the following conditions, it shall generate an Incorrect BCP Pressure exception message.

- CCD detects a BCP that for non-zero TBC is 10 psig or more higher than the target BCP (BCP High)
- CCD cannot obtain a BCP of at least 5 psig after minimum service or greater is commanded (BCP Cannot Apply). A CCD with this condition may automatically cut out.
- CCD cannot release BCP below 5 psig with a TBC=0 (BCP Stuck Brake)
- Other conditions as determined by the manufacturer

If the CCD is cut-in and the Incorrect BCP is due to a BCP Stuck brake, the CCD shall generate an Incorrect BCP exception message every 60 seconds as long as the BCP Stuck Brake condition still exists (see Section 2.4.10.2, “HEU Receives CCD Incorrect BCP Exception or Stuck Brake Exception.”)

If the CCD is cut-out and the Incorrect BCP is due to a BCP Stuck Brake, the CCD shall generate a BCP Stuck Brake exception every 60 seconds as long as the BCP Stuck Brake condition still exists (see Section 2.4.10.2, “HEU Receives CCD Incorrect BCP Exception or Stuck Brake Exception.”)

The Incorrect BCP exception and the BCP Stuck Brake exception messages shall include the actual BCP (in psig), the target BCP (in psig), current reservoir pressure, and an indication from the CCD of the reason for incorrect BCP. With the exception of the condition noted above (BCP Cannot Apply), a CCD shall not automatically cut out as a result of detecting incorrect BCP.

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2.4.10.1 Clearing CCD detects incorrect BC pressure exception or stuck brake exception

If a CCD determines that it has regained control of the BCP, it shall transmit an Incorrect BC Pressure Exception or BCP Stuck Brake Exception Cleared message. The engineer then has the option to cut in the CCD.

2.4.10.2 HEU receives CCD incorrect BCP exception or stuck brake exception

If the HEU receives an Incorrect BCP exception due to BCP Stuck Brake or BCP High from a CCD, the HEU shall automatically command the CCD to cut out in accordance with the limitations of Section 2.3.12.1.

If the HEU receives a BCP Stuck Brake exception, the HEU shall warn the engineer. This warning shall clearly indicate that the condition is a BCP Stuck Brake and that the car requires it to be manually cut out and pneumatically drained of all air. This warning may be repeated in accordance with Section 2.3.12.3.

Upon receiving an Incorrect BCP exception, the HEU shall warn the engineer of the condition, which shall clearly indicate the condition as either a BCP High, BCP Cannot Apply, or BCP Stuck Brake. If it is determined by the engineer that the CCD has failed, then the engineer can command the CCD to cut out. See Section 2.3.12, “CCD Cutout/Cut-In.”

2.4.11 Device detects multiple lead (active) HEUs in network

The lead locomotive equipment shall determine if there are multiple lead HEUs on the train. Within 10 seconds of first detecting this condition, the Lead HEU shall respond in the same manner as when it receives a multiple lead HEU exception from a trailing device (Section 2.4.11.1).

Other devices including a Trailing HEU, PSC, CCD or EOT may additionally determine that there are multiple lead HEUs on the train, and if detected, shall report a Multiple Lead HEU exception message.

2.4.11.1 HEU detects or receives multiple lead HEU exception

Upon detection of a Multiple Lead HEU condition or receipt of a Multiple Lead HEUs exception message, the Lead HEU shall broadcast HEU beacons with the mode set to Initialization and a TBC of 100% and then transition to the trail state.

2.4.12 Other local fault detected

If a network device detects a fault not listed above, it may send an exception message to the HEU in accordance with AAR Standard S-4230, “Intratrain Communication Specification for Cable-Based Freight Train Control Systems,” latest revision. The HEU shall log these exception messages for display on system diagnostic screens. High priority exception messages (e.g., hot bearing detected, wheels on the ground, severe truck hunting, severe harmonic rocking, stuck hand brake, etc.) as defined in AAR Standard S-4230, shall be displayed to the engineer.

Example exception messages that would appear only on diagnostic screens and be saved in an event recorder could include the following:

- CCD system self-diagnostic test fails
- Trailing HEU not sending status messages
- Car sensor detects worn brake shoes

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2.4.12.1 CCD detects car ID fault

The CCD shall generate a car ID fault and cut out if it detects a default or incorrect car static data.

2.4.13 Recovery from emergency, fault-induced or penalty brake applications

In all cases, an ECP brake system fault-induced full-service or full-service-penalty application shall stay in effect for 120 seconds or until the train has stopped and the penalty source has cleared. An ECP electronic emergency shall remain in effect for a minimum of 120 seconds. After the cause has been eliminated, the HEU shall provide a means for the engineer to release the interlock. Releasing the interlock shall cause an HEU that has a 120% application to transition to 100% application, or an HEU that has a 100% application to remain at 100% application, where subsequent brake controller operation shall again be permitted.

2.4.13.1 Process at locomotive for recovery from emergency, fault-induced or penalty brake applications

2.4.13.1.1 In order to recharge brake pipe after a pneumatic emergency, the locomotive's train brake handle shall be required to be moved to the release position. A prompt shall be displayed to the train operator stating that in order to charge brake pipe the train brake handle is to be moved to the release position. The TBC will re-main at 120% and the operable cars will not release brakes.

In order to recharge BP after a pneumatic emergency, BP shall be allowed to charge to release pressure when the automatic brake handle has been moved into the service zone (or release).

NOTE: Once BP has charged, brakes will gradually release in response to handle movement.

2.4.13.1.2 In order to clear an ECP brake interlock on locomotives where the TBC is controlled by the locomotive's train brake handle, the train brake handle shall be required to be moved to the full-service position. A message shall be displayed to the train operator stating that the train brake handle is to be moved to the full-service position to clear the ECP brake interlock. If the handle is moved out of the full-service position before the ECP recovery conditions are met, a message shall be displayed to the train operator to move the train brake handle back to the full-service position.

2.4.13.1.3 If the train brake handle is in the full-service position and the ECP recovery conditions are met, the ECP brake interlock shall clear without any other operator action. This will result in a TBC of 120% to transition to 100%, or a TBC of 100% to remain at 100% (until a different TBC is then requested).

2.4.13.1.4 The display shall provide an indication of the time remaining until the ECP emergency timer expires.

2.4.13.1.5 On locomotives that are equipped with an ECP TBC control device separate from the train brake handle, a means of allowing the engineer to take an action to clear the ECP brake interlock while leaving the train brake handle in release shall be provided.

2.5 Communications crosstalk mitigation

The ECP equipped train's devices communicate via a local area network. Each device is connected using the train-line as a single common communications medium. In general, communication between trains is unlikely; however certain hardware fault conditions (such as trainline ground faults) can result in some messages being exchanged between trains. This inadvertent communication is defined as a crosstalk event.

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The following Sections define the requirements related to mitigating the effects of crosstalk events. These methods define how device(s) on the trainline establish a logical connection with a single lead HEU and filter messages originating from another train.

The lead HEU Connection functions are defined in section 2.5.1. These functions establish a method for a trailing device to make a connection with the lead HEU. The message filtering functions are defined in section 2.5.2. These functions establish the criteria for determining which messages devices in the train should process and which are due to crosstalk and should be ignored.

2.5.1 Lead HEU connection

The purpose of the lead HEU Connection function is to create a logical connection between the lead HEU and other devices in the train. Prior to making a connection with the lead HEU, CCDs and Trailing HEUs shall not generate exceptions or respond to brake commands and system queries. PSCs and EOTs are required to perform some limited trainline communications prior to making a connection with the lead HEU.

2.5.1.1 Train ID

The Train ID is a value transmitted in the HEU Beacon that is intended to identify the current lead locomotive and distinguish it from other locomotives. The Train ID is defined in the AAR Standard S-4230 Communication Specification.

The Train ID is also used in messages from the Trailing HEUs, PSC, CCD and EOT to indicate to other devices which lead locomotive it is connected with.

2.5.1.2 Connection with a lead HEU

A trailing device shall connect with a lead HEU when it is NOT connected to another lead HEU. Trailing devices establish a connection with a lead HEU based on trainline power being recently present and having received multiple HEU beacons with the same source address and Train ID. If crosstalk is present and HEU beacons are being received from multiple sources, a connect flag in the HEU beacon shall be used to determine which lead HEU to connect with.

The EOT shall transmit EOT beacons while it is in the unconnected state.

The PSC shall temporarily connect with a lead HEU for purposes of determining available PSCs and establishing trainline power.

After a device has connected with the lead HEU it shall filter received messages as indicated in section 2.5.2.

2.5.1.3 Disconnecting from a lead HEU

Devices connected to a lead HEU shall disconnect from the lead HEU when the following three conditions have been met:

1. No HEU beacons are being received from the connected HEU
2. Trainline power has been off and then re-applied for at least three seconds
3. An HEU Beacon from a different HEU has been received

2.5.2 Message filtering

The purpose of the message filtering function is to allow devices connected to a lead HEU to filter messages from other devices which may be received as a result of a crosstalk event.

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2.5.2.1 HEU beacon filtering

When connected to a lead HEU, a Trailing device shall ignore HEU Beacons received with a different Train ID than the Train ID it is connected with and shall indicate in its status message that a crosstalk event has occurred.

2.5.2.2 Critical loss exception filtering

When connected to a lead HEU, a Trailing device shall ignore Critical Loss Exceptions received with a different Train ID than the Train ID it is connected with and shall indicate in its status message that a crosstalk event has occurred.

2.5.2.3 EOT beacon filtering

The lead HEU shall process EOT Beacons that have the same train ID as the lead HEU.

For purposes of initially establishing trainline power, the lead HEU shall also process EOT beacons that are not yet connected to any lead HEU.

2.5.2.4 Query and command filtering

When connected to a lead HEU, a trailing device shall ignore query and command messages received from devices other than its connected lead HEU or a standard tool (section 2.5.2.6).

2.5.2.5 Response and exception filtering

The lead HEU shall ignore any messages destined for other lead HEUs.

The lead HEU shall ignore response messages received from devices other than the device currently being queried or polled by the lead HEU.

2.5.2.6 Installation tool messages

All devices shall respond to commands and queries from a standard tool address. The standard tool addresses are specified in the AAR-S4230 communication specification.

3. Environmental requirements

The passenger ECP system shall comply with the vibration, temperature and humidity requirements specified in PRIIA documents 305-912 and 305-916.

4. Approval procedure

The approval procedure will be addressed in a future ECP standard.

5. Interoperability between freight and passenger rail

1. When setting up ECP, the operator must select passenger or freight mode of operation.
2. The selected freight or passenger mode will be broadcast to all the devices on the train.
3. Trailing passenger devices shall respond accordingly to the selected operating mode.

NOTE: When operating in freight mode, all braking will follow the freight ECP braking performance.

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Related APTA standards

APTA PR-M-S-005-98, Rev. 2.1, Code of Tests for Passenger Car Equipment Using Single Car Testing

APTA PR-M-S-020-17, Electronically Controlled Pneumatic (ECP) 26C Emulation Braking System — Performance Requirements for Passenger Applications

References

AAR Manual of Standards and Recommended Practices: AAR Standard S-401, Freight Brake Design Requirements (Adopted 1964; Last Revised: 2011)

AAR Manual of Standards and Recommended Practices: AAR Standard S-461, Performance Specification for Single Capacity Freight Brakes (Adopted 1962; Last Revised: 2002)

AAR Manual of Standards and Recommended Practices: AAR Standard S-462, Specification for Approval of Freight Car Air Brake Control Valves (Adopted 1978; Last Revised: 2002)

AAR Manual of Standards and Recommended Practices: AAR Standard S-464 Performance Testing Procedures for Freight Brakes on a 150 Car Test Rack (Adopted 1978; Last Revised 2005)

AAR Manual of Standards and Recommended Practice S-467, Code of Air Brake System Test for Freight Equipment – Single Car Test (Adopted 1977; Last Revised: 2002)

AAR Manual of Standards and Recommended Practices Electronically Controlled Brake Systems: AAR Standard S-4200, Electronically Controlled Pneumatic (ECP) Cable-Based Brake Systems – Performance Requirements (Adopted 1999; Last Revised: 2008) AAR Manual of Standards and Recommended Practices Electronically Controlled Brake Systems: AAR Standard S-4220, ECP Cable-Based Brake DC Power Supply – Performance Specification (Adopted 1999; Last Revised: 2002)

AAR Manual of Standards and Recommended Practices Electronically Controlled Brake Systems: AAR Standard S-4230, Intratrain Communications For Cable-Based Freight Train Control Systems (Adopted 1999; Last Revised: 2014)

Definitions

backup battery: The battery source that is part of the CCD and is used to power the system when the trainline power and the local car battery power are not present.

cab car: The cab car provides controlling functions to remotely operate a trail locomotive and to provide braking and traction commands. The ECP components of a cab car include elements of both HEU and CCD functionality.

car control device (CCD): The CCD is an electronic control device that replaces the function of the conventional pneumatic service and emergency portions during electronic braking and provides for electronically controlled service and emergency brake applications. The CCD interprets and acknowledges the electronic signals and controls the service and emergency braking functions on the car. In a stand-alone system, the CCD also controls reservoir charging. The CCD also will send a warning signal to the locomotive in case any of the components cannot respond appropriately to a braking command. Each CCD has a unique electronic address that is keyed to car reporting marks and number. A CCD shall be activated by presence of

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train line power. Each CCD contains a battery, which is charged from train line power. There are a number of different types of CCD applications:

- **Overlay brake system**—An overlay ECP brake system is capable of operating in either a conventionally or electronically braked train. A failure of the ECP overlay brake system would enable a train to continue to operate as a conventionally braked train using conventional control valves when the ECP brake system is placed in cutout mode. An electronically braked train must come to a complete stop before the ECP brake system can be placed into cutout mode and train operation continued with the pneumatic brake. When operating in the electronic mode, an overlay system and a pure ECP brake system must operate identically, as specified in forthcoming Sections of this standard.
- **Emulator CCD**—A CCD may optionally emulate the function of the pneumatic control valve while in a conventionally braked train. A suitable power source shall be provided to allow the emulator CCD to function as specified at all train speeds for a minimum of 48 hours. The functions and performance of pneumatic brake emulation must adhere to the requirements of AAR Standards S-461, S-462, S-464, and S-467.
- **Stand-alone CCD**—A CCD that cannot operate in a conventional pneumatically braked train and must operate only in ECP equipped trains.

car ID module: Car-specific data shall be stored in a module on the car and provided to the CCD in such a way that the CCD always contains the correct characteristics, parameters (constants), and other information for the car or brake set on which it is placed. Therefore, car-specific data shall be mechanically tied to the car in such a way that it cannot be changed inadvertently in the field, even if CCDs are swapped. Format of the car specific data is given in AAR Standard S-4230, latest revision. The CCD shall maintain a copy of the car ID information. At a minimum, this information shall contain the following:

- Vehicle reporting mark
- AAR car type
- Stretched length over pulling faces
- Loaded weight
- Empty weight
- Default full-service net braking ratio (NBR)
- Braking constant “C”
- Reservoir constant “RC”
- Minimum brake application cylinder pressure
- Presence/type of pneumatic empty/load device
- Presence of electronic empty/load device
- Number of operable brakes controlled
- Number of axles associated with CCD
- Vehicle orientation reference

ECP brake (train line) DC power supply: The ECP brake system power supply is a DC supply operating at nominally 230 Vdc to provide electrical power, via the train line, to all connected CCDs and EOT devices. The power supply is mounted within a locomotive and is controlled by a power supply controller (PSC), which is a network device. The power supply shall meet the requirements of AAR Standard S-4220, “ECP Cable-Based Brake DC Power Supply—Performance Specification,” latest revision. A single power supply shall be capable of supplying power to an ECP-equipped train consisting of a minimum of 160 CCDs and an EOT.

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emulation mode: Non-ECP mode of operation in which the electronic pneumatic components emulate the performance of the 26C control valve and follow the brake pipe for determining brake cylinder pressure.

end-of-train (EOT) device: The EOT is a device that is connected to the train line at the end of the train that contains a means of communicating with the HEU, a brake pipe pressure transducer, and a battery that charges off the train line cable. The EOT is physically the last network node in the train and transmits a status message (EOT beacon) once per second. The status message includes the current brake pipe pressure that is displayed in the cab by the HEU. If the EOT does not require an emergency brake pipe vent valve, the hose to the EOT shall be a minimum of 3/8-in. ID. The EOT also shall contain an electric train line termination circuit. This termination circuit shall be a 50-ohm resistor in series with a 0.47- μ F capacitor. The EOT shall be connected to the network and shall be transmitting status messages to the HEU before the train line power can be energized continuously. The EOT continually reports brake pipe pressure and train line voltage to the HEU. An EOT shall be activated by the presence of train line power. The requirements defined herein are those EOT functions required for ECP braked trains. The ECP EOT may be a device separate from the EOT device specified for pneumatically braked trains in the AAR Communication Manual, Part 12–15. For ECP trains capable of operating in a pneumatic mode (overlay or emulator brake systems), a pneumatic EOT function also shall be required. The ECP EOT functions may be combined in a single, dual-mode device with the pneumatic EOT functions. A dual-mode EOT device shall meet the requirements defined herein for ECP operation and the requirements for pneumatic EOTs specified in AAR Communications Manual, Part 12–15 and all applicable FRA rules. ECP equipment on a locomotive at the end of the train may perform the ECP EOT function. Locomotive ECP equipment functioning as an EOT shall meet the requirements defined in Section 4.3.21. An ECP EOT that does not also provide radio functionality does not require the annual calibration that is required of the EOT device specified for pneumatically braked trains in the AAR Communication Manual, Part 12–15.

head end train line terminator: A terminator shall be attached to the front of the train line that provides an electrical termination of the train line at the lead locomotive to minimize impedance-related communications faults. This termination circuit shall be a 50-ohm resistor in series with a 0.47- μ F capacitor. The HEU shall automatically confirm the presence of the head end train line termination. If the termination includes an ITC network device, it shall be incapable of transmitting.

head end unit (HEU): The HEU is a brake system control device mounted within the locomotive and used to control the ECP brake system. The following are the specific functions of the HEU:

- Provide a man/machine interface to operate the ECP brake system
- Provide a data display to the engineer
- Provide controls that allow the engineer to make brake commands
- Monitor the end-of-train (EOT) beacon
- Provide a control signal to turn off train line power whenever communications with the EOT is interrupted or discontinued
- Provide a control signal to command a momentary train line power application to restart CCDs that are shut down
- Provide mechanisms to conduct ECP brake system diagnostic tests
- Interface with locomotive system signals that interact with the train braking system
- Interface with the locomotive ID module in order to obtain locomotive-specific data
- Provide an interface to other locomotive system(s) with the intent of being able to provide appropriate locomotive retardation in conjunction with ECP train braking.

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locomotive ID module: Locomotive-specific data shall be stored in a locomotive ID module on the locomotive. The locomotive ID module shall provide data for the HEU and PSC in such a way that the HEU and PSC always contain the correct characteristics, parameters (constants), and other information for the locomotive on which they are placed. The locomotive-specific data shall be mechanically tied to the locomotive such that it cannot be changed inadvertently in the field even if the HEU or PSC is replaced. Format and resolution of the locomotive-specific data is given in AAR Standard S-4230, latest revision. At a minimum, this information shall contain the following:

- Locomotive road number
- Locomotive type
- Stretched length
- Nominal weight
- Number of axles
- Battery voltage fault threshold
- Battery voltage fault clear threshold
- Railroad default BBP setpoint
- Default train full-service NBR
- Suppression brake application
- Nominal wheel diameter
- Vehicle orientation reference

load weigh: Local adjustment of brake cylinder pressure based on the current weight of the vehicle.

local car battery: Battery power source provided by the passenger car backup battery. This term is used to differentiate it from the backup battery, which is an integral part of the CCD.

main reservoir equalizing pipe: Primary means of supplying air to the friction braking system on passenger vehicles.

operative brake: An operative brake is an individual brake set that is fully functional. One brake set is two braked trucks.

passenger ECP EOT: The passenger ECP EOT performs similar functions as the freight ECP EOT with the following exceptions:

- The EOT is not required to monitor the brake pipe.
- The EOT is not required to include a marker light.
- The EOT is not required to detect motion.

pneumatic backup: A pneumatic backup (PB) system shall be required on each car to apply emergency brake cylinder pressure in the event of a vented brake pipe. The PB system also shall be capable of assisting in propagating pneumatic pressure signals through the brake pipe.

power supply controller (PSC): The power supply controller (PSC) shall interface with the train line communication network and control a train line power supply as commanded by the HEU. Multiple power supplies may be enabled by the HEU as described in Section 4.3.3. The PSC shall also comply with the requirements of AAR Standard S-4220, “ECP Cable-Based Brake DC Power Supply—Performance Specification,” latest revision, and AAR Standard S-4230, “Intratrain Communication Specification for Cable-Based Freight Train Control Systems,” latest revision.

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snow brake: Means of applying a light brake cylinder pressure on a vehicle to prevent the accumulation of ice and snow between the friction material and the braking surface.

train line: The train line is a two-conductor electric wire spanning the train that carries both train line power (to operate all CCDs and EOT devices) and communications network signals (superimposed on the power voltage). The train line shall meet the requirements of AAR Standard S-4210, “ECP Cable-Based Brake System Cable, Connectors, and Junction Boxes—Performance Specification,” latest revision.

train line termination plug: A device that may be used in place of an ECP EOT to allow train line power to remain ON continuously and to allow train movement in SWITCH mode only.

Abbreviations and acronyms

AAR	Association of American Railroads
BCP	brake cylinder pressure
BP	brake pipe
BPP	brake pipe pressure
CCD	car control device
EAB	electronic air brake
ECP	electronically controlled pneumatic
EOT	end of train
HEU	head end unit
MSP	Minimum Service Pressure
PB	Pneumatic Backup
PBA	Percentage Brake Applied
PRIIA	Passenger Rail Investment and Improvement Act (2008)
PSC	Power Supply Controller
psi	pounds per square inch
PTC	positive train control
TBC	Train Braking Command
TBE	Train Braking Effort
VDC	voltage direct current
W	watts

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