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ECP Passenger Cable-Based Brake System Cable, Connectors & Junction Boxes – Performance Requirements

Passenger Car Annex to AAR S-4210

Abstract: This document establishes passenger-car requirements for an electronically controlled pneumatic (ECP) brake train line connector, cable and end-of-car junction box.

Keywords: cable, connectors, installation, junction boxes, testing

Summary: This standard establishes the minimum requirements for the cables, connectors, installation and junction boxes for ECP passenger brake equipment.

Scope and purpose: The test procedures verify that the designed components have high reliability, will withstand harsh environmental conditions and have a minimum of an eight-year service life. This document establishes passenger-car requirements for ECP brake system power and signal cable intended for use on passenger rail cars and locomotives on the United States general rail system equipped with APTA-approved ECP brake systems. The APTA passenger ECP brake system is compatible with the APTA-approved ECP brake system.

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Introduction

This introduction is not part of APTA PR-M-S-022-19, "ECP Passenger Cable-Based Brake System Cable, Connectors & Junction Boxes – Performance Requirements."

This standard applies to all:

1. Railroads that operate intercity or commuter passenger train service on the general railroad system of transportation; and
2. Railroads that provide commuter or other short-haul rail passenger train service in a metropolitan or suburban area, including public authorities operating passenger train service.

This standard does not apply to:

1. Rapid transit operations in an urban area that are not connected to the general railroad system of transportation;
2. Tourist, scenic, historic, or excursion operations, whether on or off the general railroad system of transportation;
3. Operation of private cars, including business/office cars and circus trains; or
4. Railroads that operate only on track inside an installation that is not part of the general railroad system of transportation.

ECP Passenger Cable-Based Brake System Cable, Connectors & Junction Boxes – Performance Requirements

1. Overview

This document establishes the qualification test procedure for an electric brake train line connector, cable and end-of-car junction box. The qualification test procedure is intended to verify that the designed components have high reliability, will withstand harsh environmental conditions and have a minimum of an eight-year operating life.

2. Temperature tolerances

All test temperatures stated in this document have a +2 °C tolerance.

3. General service intercar cable

3.1 General characteristics

The cable shall consist of two #8 AWG conductors and a shield. The conductors must have a minimum of two twists per foot. The cable shall be rated to 600 V and have a characteristic impedance of 50 ohms, ±10 percent.

The operating temperature range is −45 to 66 °C. The overall outside diameter must be 0.70 in. minimum to 0.75 in. maximum.

3.2 Conductors

Conductors shall be #8 AWG and consist of annealed tinned copper per ASTM B-33 and shall have rope stranding sufficient to meet flexibility requirements.

The cross-sectional area of the conductors shall be not less than 98 percent of the cross-sectional area specified. Resistance values shall be in accordance with ICEA S-66-524.

3.3 General requirements

3.3.1 The insulated wire and cable shall be suitable for electrically controlled freight brake systems for the railroad industry, and all requirements and parameters specified herein must be met.

3.3.2 The insulation shall be tight-fitting over the stranded conductors and clean stripping without damage to strands.

3.3.3 The insulation shall be fungus-resistant and shall be tested in accordance with MIL-F-13927A. After 30 days, the material must remain fungus inert.

3.3.4 The insulation thickness at any point shall be not less than 90 percent of the nominal average wall thickness to meet the requirements of Section 3.1.

3.3.5 The insulation shall have a continuous temperature rating of 90 °C as determined by test temperatures used and temperature-related parameters established herein. This cable is not certified for use within locomotive engine rooms. If cable is routed through locomotive engine rooms or near other heat-producing equipment, then the cable insulation must be rated at 125 °C.

3.4 Insulation—properties and tests

Unless otherwise stated, all testing in this section will be done on samples removed from completed cable.

3.4.1 Unaged tensile and elongation

When tested in accordance with ICEA S-66-524, the minimum values measured on insulation samples that have been removed from the conductor shall be as follows:

Tensile Strength	Elongation
750 psi	200%

3.4.2 Aged tensile and elongation

When tested as above, insulation that has been aged in a circulating air oven for 168 hours at 121 °C shall have the following minimum values:

Tensile Strength	Elongation
75% of unaged value	75% of unaged value

3.4.3 Dielectric proof test

Insulated conductors shall withstand test voltages as specified in ICEA S-66-524 for five minutes after a six-hour immersion in water. The water shall be normal tap water (conductive) and at room temperature. The sample shall be wound in a coil with a diameter 20 times the insulated diameter. The required test voltage shall be 6.0 kVac (rms) and 18 kVdc.

3.4.4 Impulse dielectric or spark test

100 percent of all wire made to this specification shall withstand either the dielectric proof test (Section 3.4.3) or a 100 percent impulse dielectric test of 18.0 kV.

3.4.5 Insulation resistance in 25 °C water

The center 20 ft section of a 25 ft length of insulated conductor shall be immersed in normal tap water that is maintained at 25 °C for 24 hours. After this conditioning period, the sample shall pass the dielectric proof test (Section 3.4.3), and the insulation resistance shall be measured per ICEA procedures. The minimum acceptable insulation resistance value shall be calculated using the insulation resistance constant value K at 10,000. Resistance is calculated as follows:

$$R = K \times \log\left(\frac{OD}{ID}\right)$$

where:
K = insulation resistance constant = 10,000

3.4.6 Long-term insulation resistance

A sample shall be immersed for 26 weeks in a water bath maintained at 90 °C and with 600 V_{rms} applied continuously. Insulation resistance measurements shall be taken weekly. The minimum acceptable insulation resistance value shall be not less than 10 MΩ based on 1000 ft after the 26-week test.

3.4.7 Long-term direct current service test

Insulation shall be evaluated for suitability for service in wet locations using the test specimens and procedure described in ICEA T-22-294. The water temperature shall be maintained at 90 °C with a continuous test voltage of 600 Vdc negative applied to the conductor. The test shall be conducted for a minimum of 16 weeks. The minimum acceptable measured dissipation factor (power factor) shall not exceed 0.05.

3.4.8 Cold bend test

3.4.8.1 The cold bend test shall be run per UL-1581, Section 580, except that the conditioning temperatures shall be −45°C; the sample shall not be removed from the cooling chamber when performing the test; and the mandrel size, tension weights, the number of turns shall be as indicated below:

Mandrel size	⅝ in.
Tension weights	10 lb
Number of turns	6

3.4.8.2 The insulation shall not exhibit visible cracks, and after bending must pass the dielectric proof test (Section 3.4.3).

3.4.9 Cold impact test

The cold impact test shall be run per UL-1581, Section 590, or per CSA C22.2 No. 0.3-92, except that the conditioning and actual test temperature shall be −45 °C.

3.4.10 Cold shock (unwind) test

3.4.10.1 A sample shall be prepared with a length not to exceed 2 ft. The mandrel, tension weights and number of turns shall be as indicated below:

Mandrel size	⅝ in.
Tension weights	10 lb
Number of turns	6

3.4.10.2 The assembly shall then be conditioned at −45 °C for a minimum of one hour. While still at −45 °C, the sample shall be unwrapped within the cold box at a speed of 15 rpm. The insulation shall not exhibit visible cracks and shall pass the dielectric proof test (Section 3.4.3).

3.4.11 Insulation shrinkage test

A 24 in. sample of completed wire shall be cut flush and straight at both ends. The sample shall be placed in a loose coil and conditioned in a circulating air oven for 168 hours at 121 °C. After the conditioning period, the sample shall be removed from the oven and allowed to cool for at least one hour at room temperature. The sample shall then be wrapped around a ⅜ in. mandrel for six turns, and insulation shrinkage at both ends shall be measured. The maximum allowable shrinkage shall be ⅛ in. on either end.

3.4.12 Aged insulation resistance test

A 25 ft sample coil of finished insulated wire shall be conditioned in a circulating air oven for 168 hours at 121 °C. After the conditioning period, the sample shall be removed from the oven and allowed to cool at room temperature for at least one hour. The sample must pass the dielectric proof test (Section 3.4.3) and shall pass the insulation resistance in 25 °C water test (Section 3.4.5).

3.4.13 Aged cold shock

A sample of finished insulated wire shall be conditioned in a circulating air oven for 168 hours at 121 °C. The sample shall then pass the cold shock (unwind) test (Section 3.4.10).

3.4.14 Penetration test

A sample of the insulated conductor, jig and plunger/chisel shall be conditioned for a minimum of one hour at 121 °C. The plunger/chisel shall consist of a metal plunger having a sharp chisel knife edge, (approximately 0.001 in. radius or less), with a provision for adding weight. The plunger/chisel shall be positioned in a suitable metal jig with a 750 g total weight. The sample shall be placed under, and at a right angle to, the plunger/chisel cutting edge. After preconditioning, the weighted plunger shall be gently lowered into contact with the cable surface. A 6 V buzzer circuit between the conductor and the plunger/chisel shall be used to indicate a test failure. The weighted plunger/chisel shall then be raised, the wire sample rotated 120 deg in the radial plane, and the test repeated. The process shall be repeated a third time, again rotating the sample 120 deg in the radial plane. The sample shall not indicate a short-circuit in 10 minutes or less in any of the three trials.

3.4.15 Crush resistance test

Finished samples of wire shall be placed between two flat steel plates (2¼ in. × 2¼ in. × ¼ in.) with corners and edges rounded to ⅛-in. radius, mounted parallel and in a horizontal plane. The plates shall be closed at a rate of 0.2 in. per minute until the conductor is grounded to either of the steel plates as indicated by a low-voltage (6 Vdc) buzzer circuit. The crush resistance shall be the average of 10 trials, all conducted at room temperature. The insulated conductor shall exhibit a crush resistance of at least 2500 lb.

3.4.16 Hot creep test

Test according to ICEA T-28-562 at 175 °C. At the conclusion of the test, the samples shall have the following minimum values:

Max. Elongation	Set
100%	5%

3.5 Fillers

Cables shall include fillers as necessary to ensure that the finished cable diameter is as specified in Section 3.1. Fillers used must be non-wicking and compatible with other cable components.

3.6 Binder

Cables may include a binder over the cable core, under the overall jacket. Additional binders may be used as necessary, dependent on cable construction and manufacturing techniques. Binders used must be compatible with other components.

3.7 Shield

The shield shall be designed to significantly reduce the effects of electromagnetic and radio frequency interference (EMI/RFI) by shielding the cable core with a tinned copper braided shield. To ensure that the shield can effectively reduce EMI/RFI, the maximum shield resistance shall be 3 Ω/1000 ft (10 MΩ per meter) at 25 °C. Minimum shield coverage is 85 percent.

3.8 Shield drain wire

The cable shall incorporate a drain wire for the shield. The drain wire shall be a minimum wire size of #22 AWG.

3.9 Jacket

A heavy-duty, flexible, low-temperature material such as polychloroprene shall be used, shall have reinforcing served thread(s) located at approximately the middle of the jacket wall, and shall meet the requirements in this section.

3.9.1 Unaged tensile and elongation

When tested in accordance with ICEA S-66-524, the minimum values measured on jacket samples that have been removed from the cable shall be as follows:

Tensile Strength	Elongation	Modulus at 200%	Set
1850 psi	200%	850 psi	20% maximum

3.9.2 Aged tensile and elongation

When tested as described in Section 3.9.1, a jacket that has been aged in a circulation air oven for 168 hours at 100 °C shall retain the following minimum values:

Tensile Strength	Elongation
80% retention of unaged value	80% retention of unaged value

3.9.3 Oil-aged tensile and elongation

When tested as described in Section 3.9.1, a jacket that has been aged in ASTM #2 oil or equivalent for 18 hours at 120 °C shall retain the following minimum values:

Tensile Strength	Elongation
80% retention of unaged value	80% retention of unaged value

3.9.4 Sunlight exposure

Test according to UL 1581, Section 1200, Sunlight Resistance. After 300 hours of exposure, the cable shall retain the following minimum values:

Tensile Strength	Elongation
85% retention of unaged value	85% retention of unaged value

3.10 Completed cable

Unless otherwise stated, all tests in this section will be done on samples of completed cable.

3.10.1 Abrasion resistance test

Test according to MIL-C-24643, except that the test apparatus shall be set up to test between the overall shield and the abrasion tool. The sample shall be in contact with the wheel for a minimum of 90 deg. The weight used shall be 2 lb. The minimum number of acceptable cycles is 500.

3.10.2 Cold bend test

The cold bend test shall be run according to Section 3.4.8, except that the mandrel size shall be 10 times the finished jacketed diameter.

3.10.3 Cold impact test

The cold impact test shall be run according to Section 3.4.9.

3.10.4 Flex test

Test a sample of completed cable according to MIL-C-13777. The bend test shall use a ⅝ in. diameter mandrel and a 50 lb weight. At the conclusion of the test, subject the cable to an insulation resistance test (Section 3.4.5).

3.10.5 Crush test

Test according to Section 3.4.15.

3.10.6 Cable Identification

The cable shall be marked throughout its length at regular intervals on the surface of the jacket or on a marker tape pulled in directly under the jacket with the following information:

APTA Specification Number
Manufacturer's Name
2/C 8 AWG, 600 V
Unique Part Number
Quarter and Year of Manufacture

3.10.7 Final electrical testing

3.10.7.1 Dielectric proof test

Measure the dielectric withstand voltage from conductor to conductor and conductor to shield. The required test voltage shall be 6.0 kVac (rms) and 18 kVdc.

3.10.7.2 Insulation resistance

Measure insulation resistance conductor to conductor and conductor to shield at 500 Vdc. The minimum insulation resistance shall be as follows:

$$R = K \times \log\left(\frac{OD}{ID}\right)$$

where:
K = insulation resistance constant = 10,000

3.10.7.3 Conductor direct current resistance

Minimum requirements shall be as described in Section 3.2.

3.10.7.4 Shield resistance

Shield resistance shall be measured in accordance with ICEA S-66-524, Section 2. Minimum requirements shall be as described in Section 3.7.

3.10.7.5 Cable characteristic impedance

Test according to ASTM D4566, Method 2, Option 1, at 250 KHz.

4. General-service undercar cable

All cable installed under the car or within the car structure must be placed in metal conduit or armored cable with the end user approval. The end-of-car cables and control portion cable to its junction box are excluded.

5. High-temperature undercar cable

This cable is intended to be thermally insulated. A cable that meets all the requirements of Section 3 but with insulation rated for temperatures higher than 90 °C may be required to meet the individual requirements of the railroad or car owner, depending on car design.

6. Connector assemblies

A connector assembly is defined as an intercar connector, cable, strength member (lanyard) and car body junction box plug connector as described in Section 9.1. The assembly may or may not be integrated with an air hose coupling.

6.1 Strength member (lanyard)

6.1.1 The strength member will be external to the cable and may either be integrated as a non-detachable part of the intercar cable or be separately removable for maintenance purposes. In either case, the strength member shall be loosely tied along the cable in multiple locations so as to protect the cable from both vertical and lateral forces. The strength member must also bear the draft pull-apart forces. It must support the connector such that the lowest point of the connector is at least 5 in. above the top of rail with the car fully loaded. In addition to the strength member, it is acceptable to use a separate chain or hose strap/support may be used that meets AAR *Manual of Standards and Recommended Practices*, Section E, Standard S-4006, to support the connector above the rail.

6.1.2 The strength member must be capable of sustaining 200 percent of the maximum pull-apart force as described in Section 7.3.1.

6.1.3 The forces exerted during any disconnection must not result in damage to the portion of the connector on the car body junction box or to the permanent wiring on the car. In the event of complete strength member failure, it is acceptable for the connector/cable to break in order to prevent damage to the junction box.

7. Intercar connector performance and testing descriptions

7.1 Visual qualification test procedure

7.1.1 Visual examination of product

The parts shall be inspected for completeness, workmanship, marking and defects.

7.1.2 Dimensional examination of product

The parts shall meet the requirements of product drawing. Parts shall have passed first article dimensional inspection.

7.1.3 Inter-mateability

Previous generation AAR-approved intercar connectors must be able to mate with any new cable assembly. Previous generation cables mated to new cables shall satisfactorily complete an insulation resistance test (Section 7.2.1), a high potential test (Section 7.2.2) and a pull-apart test (Section 7.3.1).

7.1.4 Final visual and mechanical inspection

Upon completion of testing, visually inspect each cable assembly for physical damage detrimental to the operation of the assembly.

7.2 Electrical qualification test procedure

7.2.1 Insulation resistance test

With a mated pair of connector assemblies, measure the insulation resistance from conductor to conductor and from conductor to shield with a 500 Vdc potential applied. Take the measurements after the test voltage has been applied for one minute. The insulation resistance shall be ≥500 MΩ.

> **NOTE:** Because the shield is terminated at the intercar connector, the conductor-to-shield insulation resistance measurement shall be made separately for each member of the pair.

7.2.2 High potential test (dielectric withstanding voltage)

With a mated pair of connector assemblies, conduct a high potential test with a test voltage of 2200 Vac applied conductor to conductor and each conductor to shield. Hold the test voltage for a minimum of one minute. During the test, there shall be no indication of electrical breakdown, flashover or leakage current >1.0 mA.

7.2.3 Voltage drop test

With a mated pair of connector assemblies, apply a direct current of 20 A through each conductor. Measure and record the voltage drop from car body junction box plug connector to car body junction box plug connector. Perform the test at room temperature, at −45 °C and at 66 °C after samples have stabilized. The maximum post-test voltage drop from car body junction box plug connector to car body junction box plug connector shall be 170 mV.

7.3 Mechanical and thermal qualification test procedure

7.3.1 Pull-apart test

7.3.1.1 Subject mated connectors to pull-apart force tests. Measure the pull-apart forces at room temperature, at −45 °C and at 66 °C. During the test, secure the strength member (lanyard) to the eyebolt on the intercar connector and secure the other end in a location typical to that when installed on a car. Separate the connectors at a rate of at least 2 ft/s (1.4 mph) along the centerline of the cable assemblies. Soak the connector assemblies in water at the high and low test temperatures for a sufficient time to ensure that the connector assemblies reach the required temperature.

7.3.1.2 The pull-apart forces must be no less than 30 lb and no more than 500 lb.

7.3.1.3 The eyebolt itself must be capable of withstanding 500 lb force when the strength member is pulled at an angle of 0 deg and 45 deg from the centerline of the eyebolt. Bending of the eyebolt is not a cause for failure. The strength member shall be an integrated part of the intercar connector design; therefore, no additional strength members shall be required.

7.3.2 Extreme low temperature pull-apart test (−45 °C)

7.3.2.1 Immerse an unmated pair of cables in water for four hours minimum. After removal from the water, immediately mate the cables. Prepare the cable assemblies by cooling them in a temperature chamber at −46 °C and spraying them with water mist to build up a ½ in. coating of ice. Remove the iced sample from the chamber and measure the pull-apart forces (Section 7.3.1). Repeat by recoupling the connector assemblies, putting them back in the temperature chamber, and reestablishing the ½ in.-thick ice coating. Repeat for a total of 25 pull-apart tests.

7.3.2.2 Perform an insulation resistance test (Section 7.2.1 at −45 °C), a high potential test (Section 7.2.2 at −45 °C), a voltage drop test (Section 7.2.3 at −45 °C only) and a pull-apart test (Section 7.3.1 at −45 °C only) before the first test and after the 25th pull-apart. Visually inspect connector assemblies for physical damage.

7.3.3 Extreme high-temperature pull-apart test (66 °C)

7.3.3.1 Heat a mated pair of cables to 66 ºC for 30 minutes minimum. Measure the pull-apart forces of the heated sample (Section 7.3.1). Repeat this test for 25 pull-apart cycles.

7.3.3.2 Perform an insulation resistance test (Section 7.2.1 at 66 °C), a high potential test (Section 7.2.2 at 66 °C), a voltage drop test (Section 7.2.3 at 66 °C) and a pull-apart test (Section 7.3.1 at 66 °C) after the 25th pull-apart. Visually inspect connector assemblies for damage.

7.3.4 Connector mate forces

The mate forces must never increase to the point that a normal person has difficulty coupling the connectors. It must never be necessary to use tools to couple connectors.

7.3.5 Frozen connector mate test

7.3.5.1 Immerse an unmated pair of cable assemblies in water for 24 hours minimum. Cool the unmated samples in a temperature chamber at −45 °C with the unmated ends hanging downward. Remove them from the chamber and immediately mate the connectors. Measure and record the force required to mate the connectors.

7.3.5.2 The mating forces must never increase to the point that a normal person has difficulty coupling the connectors with the unlatching mechanism in the fully unlatched position. It must never be necessary to use tools to couple connectors. It is permissible to knock the two connectors together to remove any ice before mating the connectors.

7.3.6 Frozen connector unmate forces

7.3.6.1 Immerse an unmated pair of cable assemblies in water for 24 hours minimum. Mate the samples and cool them in a temperature chamber at −45 °C. After stabilizing at −45 °C, remove the mated connectors from the chamber and manually unmate them.

7.3.6.2 The unmating forces shall never increase to the point that a normal person has difficulty unmating the connectors. It is permissible to knock the mated connectors against an object to remove any ice before unmating the connectors.

7.3.7 Durability test

7.3.7.1 Run a pair of connector assemblies through 1000 mate/pull-apart cycles at room temperature. After each pull-apart, manually mate the connector assemblies. The mate forces must never increase to the point that a normal person has difficulty coupling the connectors.

7.3.7.2 Measure the pull-apart forces at cycle numbers 250, 500, 750 and 1000. The pull-apart forces must meet the test criteria in Section 7.3.1 (room temperature only).

7.3.7.3 Measure the voltage drop before the test and after cycle numbers 1, 250, 500, 750 and 1000. Voltage drop must not exceed the criteria defined in Section 7.2.3 (room temperature only).

7.3.7.4 Perform an insulation resistance test (Section 7.2.1) and a high potential test (Section 7.2.2) as final tests. After completing 1000 cycles, visually inspect the samples for physical damage.

7.3.8 Thermal shock test

7.3.8.1 Cycle mated connectors between −45 °C and 66 °C for five cycles. Connectors must be soaked at −45 °C in one temperature chamber and then immediately placed in a second temperature chamber and soaked at 66 °C. Soak connectors at the high and low test temperatures for a sufficient time to ensure that the connectors reach the required temperature. One cycle is defined as raising the temperature of the connector and then lowering the temperature in the reverse order. Visually inspect the connector assemblies for physical damage.

7.3.8.2 At the completion of the five cycles, after reaching room temperature, conduct an insulation resistance test (Section 7.2.1), a high potential test (Section 7.2.2), a voltage drop test (Section 7.2.3, at room temperature only) and a pull-apart test (Section 7.3.1, at room temperature only).

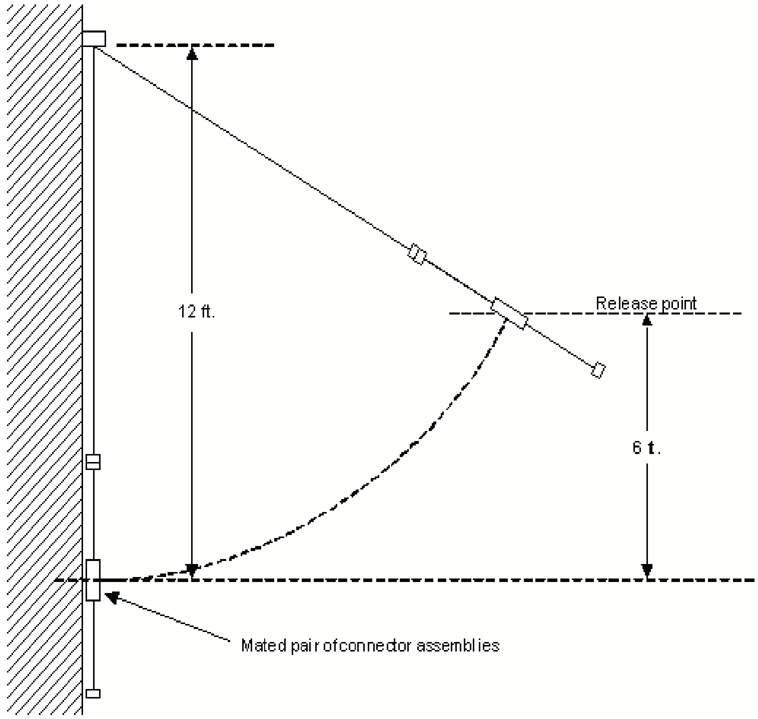
7.3.9 Impact test

7.3.9.1 Measure the initial pull-apart forces (see Section 7.3.1) and voltage drop (Section 7.2.3). Suspend a mated pair of connectors from a 12 ft long rope or cable so that the connection point of the connector assemblies just comes in contact with a concrete wall or steel beam. Pull the connectors out from the wall until the connection point is raised 6 ft and then release. The mated connector assemblies should impact while in a vertical position. The connectors must be impacted on the bottom and one side. A suggested test setup is shown in **Figure 1**.

7.3.9.2 Impact a total of eight times per axis (bottom and side). Conduct this test at room temperature, −45 °C and 66 °C. For the tests at the temperature extremes, conduct the tests within one minute from removing the connectors from the temperature chamber. Soak the connectors at the high and low test temperatures for a sufficient time to ensure that the connectors reach the required temperature.

7.3.9.3 Upon completion of conditioning, conduct an insulation resistance test (Section 7.2.1), a high potential test (Section 7.2.2), a voltage drop test (Section 7.2.3, at room temperature only) and a pull-apart test (Section 7.3.1, at room temperature only). Inspect the connector assemblies for physical damage.

FIGURE 1
Suggested Impact Test Setup



7.3.10 Drop test

7.3.10.1 Hold the car body junction box plug connector on unmated connector assemblies fixed at a point 3 ft above a concrete floor. Allow the other end of the connector assembly to freefall onto the floor from a height of 3 ft. Rotate the sample 45 deg and repeat the test. Continue rotating at 45 deg intervals and dropping onto the floor until the initial location is reached.

7.3.10.2 Upon completion of eight drops per connector assembly, mated connector assemblies shall satisfactorily complete an insulation resistance test (Section 7.2.1), a high potential test (Section 7.2.2), a voltage drop test (Section 7.2.3, at room temperature only) and a pull-apart test (Section 7.3.1, at room temperature only). Visually inspect the connector assemblies for physical damage.

7.3.11 Life test

7.3.11.1 Prior to testing, perform an insulation resistance test (Section 7.2.1) and a voltage drop test (Section 7.2.3). Place mated connector assemblies in a temperature chamber and subject them to a temperature of 107 °C for 168 hours. Apply a 460 Vdc potential between conductors throughout the test.

7.3.11.2 Upon completion of conditioning, the mated samples shall satisfactorily complete an insulation resistance test (Section 7.2.1), a high potential test (Section 7.2.2), a voltage drop test (Section 7.2.3, at room temperature only) and a pull-apart test (Section 7.3.1, at room temperature only). Visually inspect the connector assemblies for physical damage.

7.3.12 Pull-through test

7.3.12.1 The forces exerted during any disconnection must not result in damage to the end-of-car connector on the car body junction box or to the permanent wiring on the car. In the event of complete connector pull-apart failure, it is acceptable for the connector/cable to break in order to prevent damage to the junction box.

7.3.12.2 The car body junction box connector on the cable assemblies shall be installed onto a junction box end-of-car connector. Clamp the cable and measure and record the force required to separate the cable or plug connector from the junction box end-of-car connector. Apply the force 90 deg (directly in line with the centerline of the cable) to the junction box end-of-car connector. Perform the test at room temperature, at −45 °C and at 66 °C.

7.3.12.3 The force required to separate the cable or plug connector from the junction box shall be no more than 800 lb. After testing, visually inspect the end-of-car connector on the junction box for physical damage.

> **NOTE:** It is not necessary to use complete connector assemblies as long as the junction box connector is intact.

7.3.13 Junction box plug connector coupling nut over-torque test

Secure the junction box and tighten the plug connector's coupling nut using a standard 2¼ in. wrench (or similar) that touches only two flats on the nut (do not use a socket). Torque the nut to 265 ft-lb. Perform the tests at room temperature, at −45 °C and at 66 °C. Remove the nut and visually inspect the junction box and connector for physical damage. The nut must not damage the car body junction box plug connector or the junction box itself.

7.3.14 Vibration and shock test

7.3.14.1 Conduct a vibration and shock test using two mated pairs. Include vibration and shock tests at ambient temperature. Also test in at least one axis at −45 ºC and 66 ºC.

7.3.14.2 Complete baseline random vibration profiles in each axis. Also complete in each axis accelerated vibration profiles that demonstrate 70,080 hours (eight years) of operating field life at 100 percent duty cycle.

7.3.14.3 Complete shock tests in each axis.

7.3.14.4 At the conclusion of the vibration and shock tests, conduct the following post-vibration/shock tests:

- Visual and mechanical inspection
- Insulation resistance (Section 7.2.1)
- High potential test (Section 7.2.2)
- Voltage drop (Section 7.2.3 at room temperature)
- Pull-apart forces (Section 7.3.1 at room temperature)

7.3.14.5 Use the following baseline random vibration profiles in each axis as indicated in **Table 1**:

TABLE 1
Baseline Random Vibration Profiles

Vertical axis (PSD= 1.63 G_{rms})

Freq. (Hz)	G^2/Hz	Freq. (Hz)	G^2/Hz
5.00	0.00115	65.10	0.04800
6.85	0.00590	76.80	0.00677
7.80	0.00816	84.15	0.01290
10.35	0.00303	102.65	0.00262
11.80	0.00583	107.95	0.00540
20.85	0.00712	145.35	0.00580
23.75	0.01120	165.65	0.02300
28.35	0.00370	172.50	0.01520
35.80	0.04950	200.30	0.00228
40.45	0.03590	238.25	0.00494
48.20	0.01380	248.55	0.01740
57.10	0.07530	250.00	0.00447
61.30	0.00530		

Longitudinal axis (PSD= 1.16 G_{rms})

Freq. (Hz)	G^2/Hz
5.0	0.00100
8.5	0.00598
80.0	0.00516
115.0	0.01800
150.0	0.00171
161.0	0.00705
250.0	0.00150

Lateral axis (PSD= 0.896 G_{rms})

Freq. (Hz)	G^2/Hz	Freq. (Hz)	G^2/Hz
5.00	0.00125	94.85	0.00166
6.37	0.00615	98.70	0.00348
9.65	0.00357	125.70	0.00146
10.90	0.00818	136.50	0.00495
13.80	0.00967	148.50	0.00385
19.45	0.00204	156.95	0.00160
27.95	0.00536	161.30	0.00339
35.70	0.00345	170.85	0.00387
39.60	0.00665	182.70	0.00140
43.10	0.00262	248.80	0.00365
46.40	0.00960	250.00	0.00100

7.3.14.6 **Figure 2** defines the accelerated random vibration profiles (or their equivalent) that shall be run for all axes to demonstrate 70,080 hours (eight years) of operating field life at 100 percent duty cycle.

FIGURE 2
Accelerated Vibration Parameters—All Axes

$$Nf = 70080 \quad \text{Hours}$$

$$b = 6.4 \quad \text{Electronics}$$

$$\frac{(GRMSt)/(GRMS)}{f} = 3.0 \quad \text{(ratio)}$$

$$N_T = \left[\frac{1}{(GRMSt)/(GRMSf)}\right]^b \times Nf$$

$$= \left[\frac{1}{3.5}\right]^{6.4} \times 70080$$

$$= 62 \text{ hours (each axis)}$$

$$\text{Rescale} = 9.54 \text{ dB}$$

7.3.14.7 Use the following shock test parameters:

Level	=	20 G
Time Base	=	10 ms
Quantity	=	15 positive 15 negative

7.3.14.8 Use the following test procedure, or equivalent:

Step	Action
Vertical vibration/shock tests	
1	Conduct the vertical PSD = 1.63 G_{rms} baseline random vibration profile for 30 minutes at ambient temperature.
2	Conduct the accelerated vibration profile for 62 hours at ambient temperature, at −45 °C and at 66 °C. Divide the 62 hours into an approximately equal time period (~20 hours, 40 minutes) at each of these temperatures.
3	Conduct the shock test at ambient temperature.
Longitudinal vibration/shock tests	
1	Conduct the longitudinal PSD = 1.16 G_{rms} baseline random vibration profile for 30 minutes at ambient temperature.
2	Conduct the accelerated vibration profile for 62 hours at ambient temperature.
3	Conduct the shock test at ambient temperature.
Lateral vibration/shock tests	
1	Conduct the longitudinal PSD = 0.896 G_{rms} baseline random vibration profile for 30 minutes at ambient temperature.
2	Conduct the accelerated vibration profile for 62 hours at ambient temperature.
3	Conduct the shock test at ambient temperature.

7.4 Environmental qualification test procedure

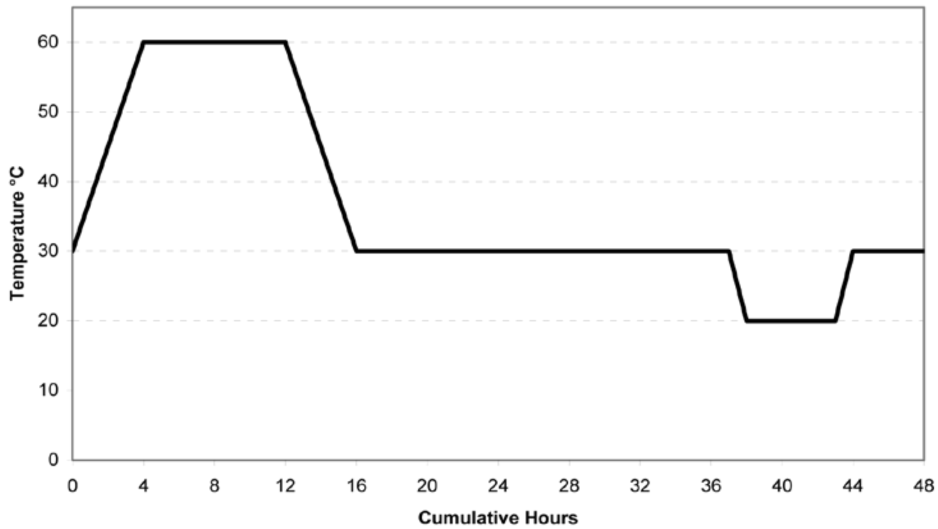
7.4.1 Humidity/temperature test

7.4.1.1 Run a pair of connector assemblies through five humidity/temperature cycles. Prior to testing, precondition the samples at 25 °C, 50 percent (±5 percent) relative humidity (RH) for 24 hours. After preconditioning, the mated samples shall satisfactorily complete an insulation resistance test (Section 7.2.1) and a high potential test (Section 7.2.2).

7.4.1.2 Mount the mated connector assemblies horizontally in an environmental chamber with the car body junction box plug connectors mated and wired to junction box receptacle connectors. Direct the wires from the junction box receptacle connectors through sealed portholes out of the humidity chamber.

7.4.1.3 A humidity-temperature cycle is defined as a 48-hour period as detailed in **Figure 3**.

FIGURE 3
Aggravated Humidity-Temperature Cycle Constant RH of 95% (±4%)



7.4.1.4 After 2.5 and five cycles, the mated sample shall satisfactorily complete an insulation resistance test (Section 7.2.1) and a high potential test (Section 7.2.2) within the chamber.

7.4.1.5 After the last cycle, remove the samples from the chamber and allow them to return to room temperature and ambient RH for 24 hours. After conditioning, the sample shall satisfactorily complete an insulation resistance test (Section 7.2.1), a high potential test (Section 7.2.2), a voltage drop test (Section 7.2.3) and a pull-apart test (Section 7.3.1).

7.4.1.6 Upon completion of the humidity test, visually inspect the samples for physical damage.

7.4.2 Salt spray test

7.4.2.1 Subject two unmated connectors to a salt spray per MIL-STD-1344A, Method 1001.1, Test Condition A.

7.4.2.2 Upon completion of conditioning, mate connectors. Perform an insulation resistance test (Section 7.2.1), a high potential test (Section 7.2.2), a voltage drop test (Section 7.2.3, at room temperature only) and a pull-apart test (Section 7.3.1, at room temperature only). Visually inspect the connector assemblies for physical damage.

7.4.3 Wet mate test

7.4.3.1 The purpose of this test is to verify the water absorption characteristics of the connector's material when subjected to the tests in Section 7.4.3.2. Therefore, any excessive surface water that may be present after immersing in the water may be removed before mating the connectors. Immerse two unmated connector assemblies in tap water at room temperature for a minimum of 24 hours. Remove connectors from water, remove any excessive surface water that may be present, and immediately mate the connectors in the horizontal position while the connectors are still wet.

7.4.3.2 Immediately subject the mated samples to an insulation resistance test (Section 7.2.1). Also subject the mated samples to a high potential test (Section 7.2.2), a voltage drop test (Section 7.2.3, at room temperature only) and a pull-apart test (Section 7.3.1, at room temperature only).

7.4.4 Sunlight exposure test

7.4.4.1 Subject mated connector assemblies to 300 hours of sunlight exposure in accordance with UL 1581, Section 1200.

7.4.4.2 After the test, conduct an insulation resistance test (Section 7.2.1), a high potential test (Section 7.2.2), a voltage drop test (Section 7.2.3, at room temperature only) and a pull-apart test (Section 7.3.1, at room temperature only). Visually inspect the cable and connector assemblies for cracks or physical damage.

7.4.5 Sand/dust exposure test

Test the mated connectors according to MIL-STD-202, Method 110. After the sand immersion cycles, conduct an insulation resistance test (Section 7.2.1), a high potential test (Section 7.2.2), a voltage drop test (Section 7.2.3, at room temperature only) and a pull-apart test (Section 7.3.1, at room temperature only). Visually inspect the connector assemblies for physical damage.

7.4.6 Fluid resistance test

7.4.6.1 Test the unmated connector samples according to MIL-STD-1344, Method 1016 (one sample per fluid). The test fluids will be diesel fuel, lubricating oil (fluid type D), isopropyl alcohol (fluid type I) and sulfuric acid (0.5 percent concentration). Method 1016 specifies the number of cycles, temperatures and duration of fluid exposure.

7.4.6.2 After the fluid immersion cycles, mate the connectors without wiping them off and then conduct an insulation resistance test (section 7.2.1), a high potential test (section 7.2.2), a voltage drop test (section 7.2.3 at room temperature only), and a pull-apart test (section 7.3.1 at room temperature only).

7.4.7 Blowing rain test

7.4.7.1 Mate the car body junction box plug connectors to junction box receptacle connectors. Test the connector samples according to MIL-STD-810E, Method 506.3, Procedure 1. Orient the mated connector assemblies with junction boxes in their normal operating positions during the test.

7.4.7.2 Adjust wind velocity to 40 mph and maintain for at least 30 minutes. Verify the air velocity prior to start of rain and placement of the sample. Verify prior to starting the test that the rainfall rate is set to 5.8 in. per hour.

7.4.7.3 Disperse the rain completely over the test item with the wind blowing at 40 mph for 30 minutes. Rotate the sample 90 deg to expose another side of the connector assemblies to the blowing rain. Repeat until a 360 deg rotation has been completed.

7.4.7.4 After the exposure to blowing rain, the mated connector assemblies shall satisfactorily complete an insulation resistance test (Section 7.2.1), a high potential test (Section 7.2.2), a voltage drop test (Section 7.2.3, at room temperature only) and a pull-apart test (Section 7.3.1, at room temperature only).

7.4.7.5 Unmate the connector assemblies and visually inspect them for ingress of water into the connectors and for physical damage.

8. Test sequence

Use the following sequence for testing the product:

TABLE 2
Test Sequence

	Test Group						
Test or Examination	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Quantity (Mated Pair)	**One**	**Two**	**One**	**One**	**Four**	**One**	**Two**
	Sequence						
Visual Qualification							
7.1.1 Visual examination of product	1	1	1	1	1	1	1
7.1.2 Dimensional examination of product	2						
7.1.3 Inter-mateability	3	2	2	2	2	2	2
7.1.4 Final visual and mechanical inspection	28	19	17	12	12	27	8
Mechanical Qualification							
7.2.1 Insulation resistance test	4, 9, 14, 19, 24	3, 8, 13	3, 8, 13	3, 8	3, 8	3, 8, 13, 18, 23	4
7.2.2 High potential test (dielectric withstanding voltage)	5, 10, 15, 20, 25	4, 9, 14	4, 9, 14	4, 9	4, 9	4, 9, 14, 19, 24	5
7.2.3 Voltage drop test	6, 11, 16, 21, 26	5, 10, 15	5, 10, 15	5, 10	5, 10	5, 10, 15, 20, 25	6
7.3.1 Pull-apart test	7, 12, 17, 22, 27	6, 11, 16	6, 11, 16	6, 11	6, 11	6, 11, 16, 21, 26	7
7.3.2 Extreme low temperature pull-apart test (−45 °C)			7				
7.3.3 Extreme high temperature pull-apart test (66 °C)			12				
7.3.5 Frozen connector mate test		18					
7.3.6 Frozen connector un-mate test		17					
7.3.7 Durability test	8						
7.3.8 Thermal shock test		7					
7.3.9 Impact test	23						
7.3.10 Drop test	18						
7.3.11 Life test						12	
7.3.12 Pull-through force test					13		
7.3.13 Junction box plug connector coupling nut over-torque test	29						
7.3.14 Vibration and shock test							3

Environmental Qualification							
7.4.1 Humidity/temperature test				7			
7.4.2 Salt spray test						22	
7.4.3 Wet mate test						7	
7.4.4 Sunlight exposure test		12					
7.4.5 Sand/dust exposure test						17	
7.4.6 Fluid resistance test					7		
7.4.7 Blowing rain test	13						

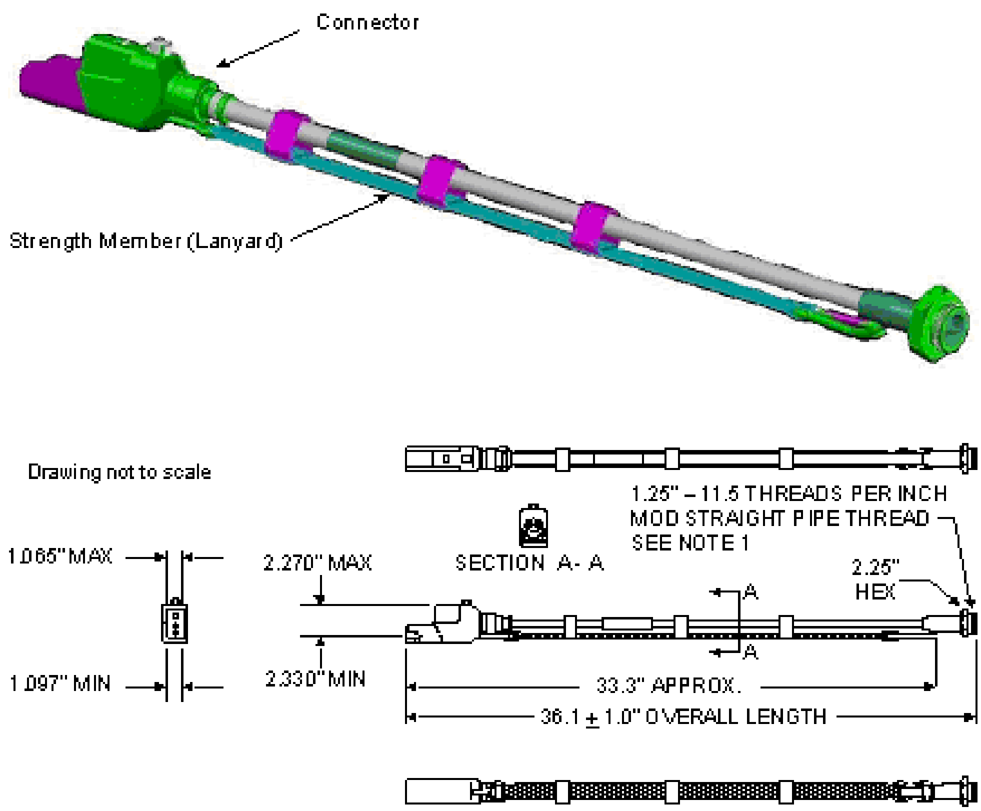
9. Car body connections

9.1 Connections

9.1.1 A connector assembly shall include an intercar connector, cable, strength member (lanyard) and car body junction box plug connector as shown in **Figure 4**.

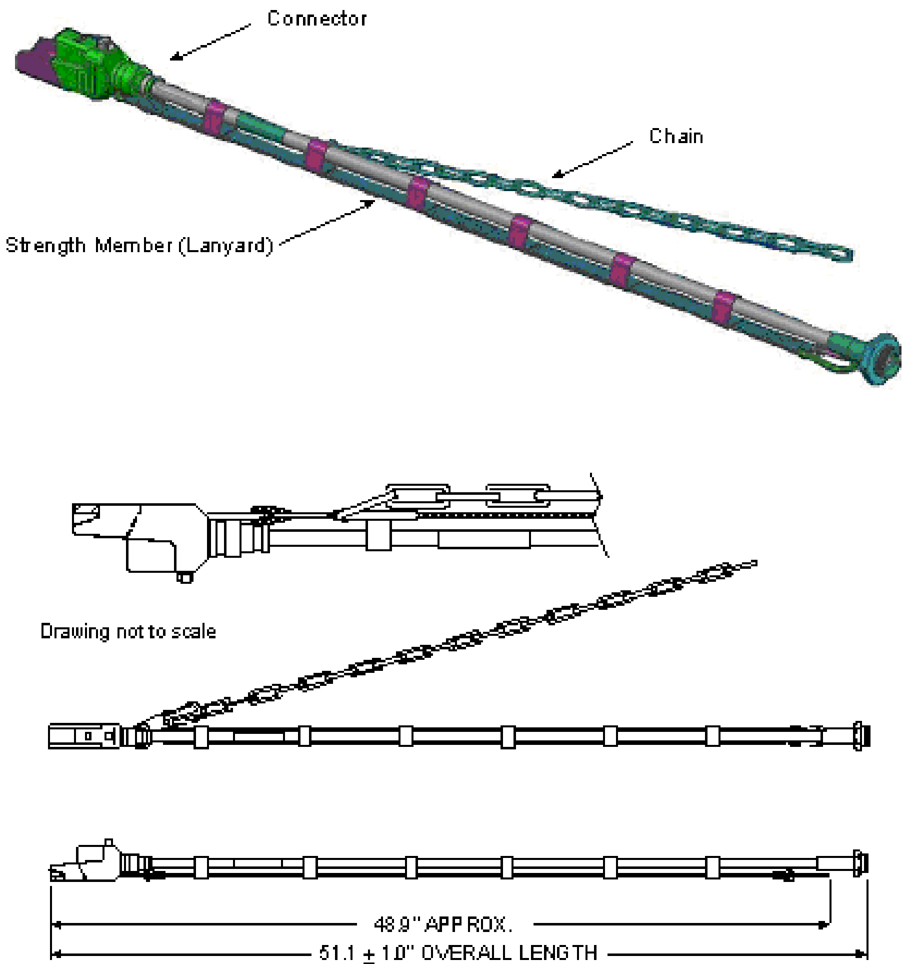
9.1.2 The junction box connector must be able to be installed and removed by use of a standard wrench (2¼ in.) used for installation of AAR brake hoses.

FIGURE 4
Connector Assembly for Cars



Notes:
1. Dry film lubricant to be applied to the threads of the nut
2. When installed on the car, lanyard spring clip must be fastened approximately flush with or slightly behind mounting face of nut
3. Approximate weight: 2.3 lb

FIGURE 5
Connector Assembly for Locomotives



Notes:
1. Dry film lubricant to be applied to the threads of the nut
2. When installed on the car, lanyard spring clip must be fastened approximately flush with or slightly behind mounting face of nut
3. Approximate weight: 2.3 lb
4. All connector dimensions identical to those shown in **Figure 4**.

9.2 Junction box

The assembled junction box or enclosure at the end sill of the car may optionally have drain holes in the bottom of the box or enclosure. If drain holes are not present, then the box or enclosure shall be sealed against moisture on all sides. The junction box removable covers shall be secured with captive screws/fasteners to prevent loss of these items during inspection and repairs. The car-to-connector interface on the junction box shall be such that a second wrench will not be required when installing or removing the intercar connector.

9.3 Car body connector mounting envelope

For the correct end-of-car connection location, refer to APTA PR-M-RP-M-001-97, latest revision, “Air Connections, Location and Configuration of, for Passenger Cars Equipped with APTA Long Shank Tight Lock or Similar Long Shank Type Couplers.”

9.4 Cable length

The length of the entire connector assembly shall be 36 in., ±1 in., for cars and 51 in., ±1.5 in., for locomotives and cars with S-4021 end arrangements. This length is the total length as measured between the end of the car-to-car connector and the mating face of the junction box plug on the other end of the connector/cable assembly.

9.5 Car body wire connections

9.5.1 Connections

All wiring connections on the car itself, for example from the main cable to the CCD, will use low-resistance ring terminals and crimped connections or an AAR-approved alternate. The ring terminals shall be bolted to suitably sized terminal posts with locknuts and plain washers or plain nuts with shake-proof washers, capable of withstanding a vibration level of ±5 G over a frequency range of 20–80 Hz.

9.5.2 Connection resistance

The electrical resistance of bolted and crimped connections shall not exceed 10 mΩ.

9.5.3 Cable shield grounding

The cable shield shall be grounded to the car body at the junction box using ring terminals crimped to the drain wire bolted to terminal posts as specified in Section 9.5.1.

10. Crimp strength

The sample contact shall be attached to the specified #8 AWG wire and placed in a standard tensile-testing machine. Sufficient force shall be applied to pull the wire out of the sample contact or break the wire or sample. The travel speed of the head shall be 1 in. per minute. The clamping surfaces may be serrated to provide sufficient clamping force. During the pull test, the sample contact shall not break or separate from the wire before the minimum tensile strength of 150 lb is reached. This test applies to the contacts in the car body connector and all contacts on the intercar connector.

11. Production requirements

All connector assemblies must be subjected to a dielectric proof test as described in Section 3.10.7.1 prior to shipment.

12. Approval procedure

12.1 The manufacturer will apply in writing to the Chief—Technical Standards, Transportation Technology Center Inc., P.O. Box 11130, 55500 DOT Road, Pueblo, CO 81001, to initiate the approval process. This application for approval will include a description of the product and its intended use.

12.2 The manufacturer will, at no expense to APTA, provide a sample of each cable and/or connector.

12.3 The manufacturer will supply at least 500 ft of production cable, or 50 production connector assemblies, from which an AAR representative will select the necessary test samples.

12.4 The manufacturer will provide test data and certify that the cable and/or connector meets all requirements of this standard. Testing must be performed or witnessed by the AAR Research and Test Department, or be conducted by a certified outside laboratory.

12.5 After the PRESS Mechanical Group has examined the cable and supporting information, it will notify the manufacturer or supplier as to whether the product has been given a conditional approval or has been disapproved.

Related APTA standards

APTA PR-M-RP-001-97, "Air Connections, Location and Configuration of, for Passenger Cars Equipped with APTA Long Shank Tight Lock or Similar Long Shank Type Couplers"

The following standards are the complete set of Passenger ECP standards:

APTA PR-M-S-020-17, "Passenger Electronic 26C Emulation Braking System – Performance Requirements"
APTA PR-M-S-021-17, "ECP Passenger Cable-Based Braking System – Performance Requirements"
APTA PR-M-S-022-19, "ECP Passenger Cable-Based Brake System Cable, Connectors and Junction Boxes – Performance Requirements"
APTA PR-M-S-023-19, "ECP Passenger Cable-Based Brake DC Power Supply – Performance Requirements"
APTA PR-M-S-024-19, "Intratrain Communication Requirements for ECP Cable-Based Passenger Train Control Systems"
APTA PR-M-S-025-19, "ECP Passenger Cable-Based and Passenger Emulation Braking System – Approval Procedure"
APTA PR-M-S-026-19, "ECP Passenger Cable-Based Braking System – Interoperability Procedure"
APTA PR-M-S-027-19, "ECP Passenger Cable-Based Braking System – Configuration Management"

References

Association of American Railroads
AAR S-4006 Hose Supports – Performance Testing

ASTM International standards:
ASTM B-8, Standard Specification for Concentric Stranded Copper for Electrical Conductors
ASTM B-33, Tinned Soft or Annealed Copper Wires
ASTM B-172, Standard Specification for Rope Lay Stranded Copper Conductors Having Bunch-Stranded Members for Electrical Conductors
ASTM B298, Standard Specification for Silver-Coated Soft or Annealed Copper Wires
ASTM B355, Standard Specification for Nickel-Coated Soft or Annealed Copper Wires
ASTM D4566, Standard Test Methods for Electrical Properties of Insulation and Jackets for Telecommunications Wire and Cable

CSA C22.2, No. 0.3-92, Test Methods for Electrical Wires and Cables

Insulated Cable Engineers Association (ICEA) standards:
ICEA S-66-524, Cross-Linked Thermosetting Polyethylene Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy
ICEA T-22-294, Test Procedures for Extended Time Testing for Wire and Cable Insulation for Service in Wet Locations
ICEA T-28-562, Hot Creep

National Electrical Manufacturers Association, NEMA 4, Plugs, Receptacles, and Cable Connectors

UL 1581, Reference Standard for Electrical Wires, Cables, and Flexible Cords

United States defense standards:
MIL-C-13777, Cables, Special Purpose, Electrical
MIL-C-24643, General Specification for Cables and Cords, Electrical, Low Smoke, for Shipboard Use
MIL-F-13927A, Electrical, Fungus Resistance Tests
MIL-STD-1344A Test Methods for Electrical Connectors

MIL-STD-202F Sand and Dust

Definitions

pull-apart: Uncoupling the connectors by uncoupling the cars. Pull-apart forces must be through the external strength members.

un-mate: Uncoupling the connectors manually without uncoupling the cars themselves.

Abbreviations and acronyms

Ω	ohms
A	amperes
AAR	Association of American Railroads
ECP	electronically controlled pneumatic
EMI	electromagnetic interference
ICEA	Insulated Cable Engineers Association
K	insulation resistance constant
kVac	kilovolts alternating current
kVdc	kilovolts direct current
MΩ	megohms
mA	milliamperes
NATSA	North American Transportation Services Association
PSD	power spectral density
RFI	and radio frequency interference
RH	relative humidity
rms	root-mean-square
Vdc	volts direct current

Summary of document changes

- This is the first publication of this document.

Document history

Document Version	Working Group Vote	Public Comment/ Technical Oversight	CEO Approval	Policy & Planning Approval	Publish Date
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First revision	—	—	—	—	—