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Electrical Working Group

480 Vac Head End Power Jumper and Receptacle Hardware

Abstract: This document defines the recommended practices for head end power (HEP) jumper/receptacle hardware.

Keywords: 480 Vac hardware, head end power system, trainline

Summary: This recommended practice defines the performance requirements, design features and hardware interface dimensions of the 480 Vac HEP trainline jumper cables and receptacles.

Foreword

The American Public Transportation Association is a standards development organization in North America. The process of developing standards is managed by the APTA Standards Program's Standards Development Oversight Council (SDOC). These activities are carried out through several standards policy and planning committees that have been established to address specific transportation modes, safety and security requirements, interoperability, and other topics.

APTA used a consensus-based process to develop this document and its continued maintenance, which is detailed in the manual for the APTA Standards Program. This document was drafted in accordance with the approval criteria and editorial policy as described. Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

This document was prepared by the Electrical Working Group as directed by the Passenger Rail Equipment Safety Standards Policy and Planning Committee.

This document represents a common viewpoint of those parties concerned with its provisions, namely transit operating/planning agencies, manufacturers, consultants, engineers and general interest groups. The application of any recommended practices or guidelines contained herein is voluntary. APTA standards are mandatory to the extent incorporated by an applicable statute or regulation. In some cases, federal and/or state regulations govern portions of a transit agency's operations. In cases where there is a conflict or contradiction between an applicable law or regulation and this document, consult with a legal adviser to determine which document takes precedence.

This document supersedes APTA PR-E-RP-018-99, Rev. 1, which has been revised. Below is a summary of changes from the previous document version:

- Updated working group roster; format updated to latest APTA standards format.
- Addition of Summary section.
- Addition of Foreword section.
- Added applicability language in the Introduction.
- Added power car as a vehicle type throughout document.
- Merged former sections 1.1, Scope, and 1.2, Purpose, into Scope and Purpose.
- Revised figures in former section 10, Illustrations. Redistributed revised figures in appropriate places within document.
- Moved former section 2, References, to the new sections Related APTA standards and References.
- Moved former section 3, Definitions, abbreviations and acronyms into new sections Definitions and Abbreviations and Acronyms.
- Renumbered former section 4, Performance requirements, to new section 1.
    - Renumbered former section 4.1, General, to new section 1.1. Added functional description of 480 Vac head end power jumper and receptacle hardware.
    - Adde new section 1.1.1, Application to vehicles.
    - Added new Figure 1, Typical Consist HEP Jumper Cable Arrangement.
- Renumbered former section 5, Receptacles, to new section 2.
    - Revised and renamed former Figure 2, Receptacle housing, to 480 Vac, 400 A Receptacle Housing.

- Revised, renumbered and renamed former Figure 1, Plug/receptacle interface, to new Figure 3, 480 Vac, 400 A Plug and Receptacle Interface.
    - Revised and renamed former Figure 4, Receptacle, to 480 Vac, 400 A Receptacle Assembly.
    - Added new section 2.2.1.1, Integrally molded. Adde functional description of integrally molded receptacles.
    - Added new section 2.2.1.2, Pre-molded. Adde functional description of pre-molded receptacles.
    - Renumbered former section 5.2.4, Engaging reinforcement, to new section 2.2.4. Added recommendation for a molded in stabilizing ring.
    - Renumbered former section 5.2.7, Contact retaining force, to new section 2.2.7. Revised recommended 4/0 contact withstand force from 400 lb to 600 lb minimum. Revised recommended #10 contact withstand force from 40 lb t5o 150 lb minimum.
- Renumbered former section 6, Jumper cable assemblies, to new section 3.
    - Revised and renamed former Figure 5, Portable jumper, to 480 Vac, 400 A Portable Jumper Cable Assembly.
    - Added new section 3.1.1.1, Integrally molded. Added recommendations for integrally molded jumper cables.
    - Added new section 3.1.1.2, Pre-molded. Added recommendations for pre-molded jumper cables.
    - Revised and renamed former Figure 6, Fixed jumper, to Flange-Mounted Cable Grip, Fixed Jumper.
    - Added new Figure 7, 480 Vac, 400 A Fixed Jumper Cable Assembly.
    - Revised, renumbered and renamed former Figure 7, Adapter jumper, to new figure 8, 480 Vac, 400 A Adapter Jumper Cable Assembly.
    - Revised, renumbered and renamed former Figure 8, Looping jumper, to new figure 9, 480 Vac, 400 A Looping Jumper.
    - Added new section 3.4.2, Plug body and contacts. Added recommendation for stainless steel strain-relief cable.
    - Added new section 3.4.3, Cable length. Added recommendation for stainless steel strain-relief cable length for 3/10 cord.
    - Added new section 3.5, Connector jumper.
    - Added new section 3.5.1, Description of assembly. Added description of connector jumper assembly
    - Added new section 3.5.2, Receptacle body and contacts. Added recommendations for connector jumper receptacle body and contacts.
    - Added new section 3.5.3, Manufacturer's mark and date. Added marking recommendations.
    - Added new Figure 10, 480 Vac Connector Jumper.
- Renumbered former section 7, wire, to new section 4.
    - Renumbered former section 7.2.4, Jacket, to new section 4.2.4. Added recommended properties for wire jacket.
- Renumbered former section 8, Acceptance tests on all receptacles and jumpers, to new section 5.
- Renumbered former section 9, Qualification tests, to new section 6.
    - Added new section 6.4.6, Sectioning. Added sectioning recommendations for plug and receptacle.
    - Added new Figure 11, Sectioning of Receptacle.
    - Added new Figure 12, Sectioning of Plug.

- Revised, renumbered and renamed former Figure 9, Temperature rise test measurement locations, to new figure 13, Temperature Rise Test – Location of Thermocouples.
- Revised, renumbered and renamed former Figure 10, Contact resistance test measurement locations, to new figure 14, Contact Resistance Millivolt Drop Test – Measurement Points.

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Introduction

This introduction is not part of APTA PR-E-RP-018-99, "480 Vac Head End Power Jumper and Receptacle Hardware."

This recommended practice applies to all:

- railroads that operate intercity or commuter passenger train service on the general railroad system of transportation; and
- 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 recommended practice does not apply to:

- rapid transit operations in an urban area that are not connected to the general railroad system of transportation;
- tourist, scenic, historic or excursion operations, off the general railroad system of transportation;
- operation of private cars, including business/office cars and circus trains unless otherwise required by other standards or regulations;
- railroads that operate only on track inside an installation that is not part of the general railroad system of transportation; or
- vehicle-to-vehicle interfaces that are permanently or semi-permanently coupled within trainsets; however, the exposed ends are still subject to this recommended practice.

Scope and purpose

This document defines the recommended practices for 480 Vac jumper cable and receptacle hardware for new and existing equipment. System requirements for the use of the components defined in this document are described in APTA PR-E-RP-016-99, "480 Vac Head End Power System."

The purpose is to define recommended practices for 480 Vac jumper cable and associated receptacle hardware, both for construction standards and to ensure mutual mechanical compatibility among products manufactured by different vendors.

480 Vac Head End Power Jumper and Receptacle Hardware

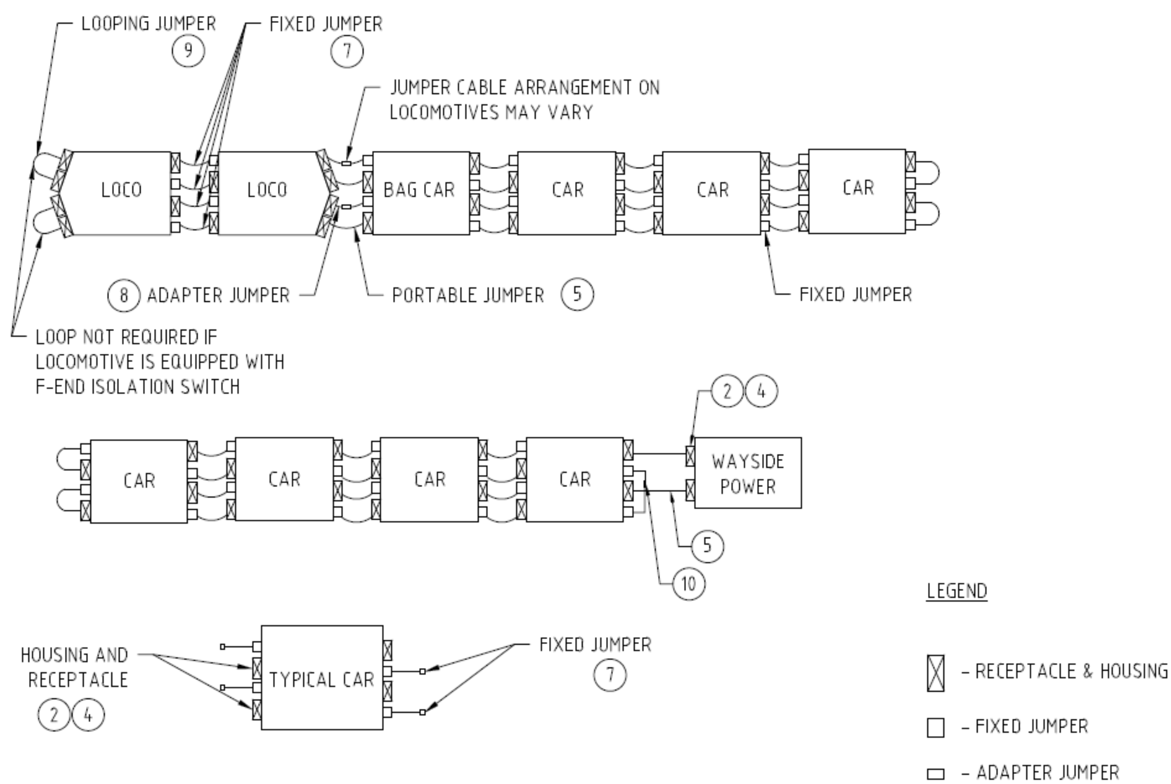
1. Performance requirements

1.1 General

Jumper cable assemblies and receptacles are used for transmission of 480 V, 3 Phase, 50/60 Hz "head end power" locomotive-to-locomotive, locomotive-to-car, car-to-car, and with DMUs. In this arrangement, four cables are generally used in a parallel arrangement between each vehicle. Cable assemblies are also used to provide wayside power to a consist; this is generally done with two cables in a parallel arrangement. See **Figure 1**.

1.1.1 Application to vehicles

FIGURE 1
Typical Consist HEP Jumper Cable Arrangement



NOTE: Circled numbers above refer to figures in the document. A DMU can be of the car types.

1.1.2 Rating

The rating of the mated jumper and receptacle contacts should be 600 Vac, 400 A for power contacts and 600 Vac, 40 A for control contacts, minimum continuous over the full operating temperature range of −40 °C to +60 °C.

1.1.3 Keying

Plugs and receptacles should be keyed through the use of a polarized power pin with a larger diameter than the other contacts.

1.1.4 Mating force

The force required to manually mate a jumper cable with the receptacle should be 50 lb ±20 lb.

1.1.5 Jumper head retention in the receptacle

When applied to a vehicle or wayside power outlet, the jumper should be the weakest link of the jumper/receptacle marriage. The connection should separate without damage to plug or receptacle should the vehicles be uncoupled or moved before any jumpers are disconnected.

1.1.6 Protection by control pin design

The jumper receptacle/plug used should be designed so that control pins are the first to break connection and the last to make connection relative to the power pins. The conductor connected to the control pins should be used to establish a trainline complete (TLC) signal. The absence of a trainline complete signal should prevent energizing the HEP trainline.

1.1.7 Watertightness and weatherproofness

The mating of cable assemblies should provide a connection that is weatherproof when exposed to the conditions described in APTA PR-E-RP-016-99, "480 Vac Head End Power System," sections 1.7 and 2.1. With a jumper fully seated in an outlet/receptacle, a watertight seal should be provided between the mated parts. The sealing bosses at the base of each contact pin, in conjunction with the sealing lip in the contact entry of the mating plug, should form the primary seal between contacts. The secondary seal should be between the circumference of the plug body and the bore of the receptacle body.

1.2 Environment

The receptacles and jumper cables should be designed and manufactured to operate reliably and without degradation under the following environmental conditions or with any additional requirements as specified by the authority:

- Exposure to weather typically experienced throughout the United States
- Direct sunlight
- Temperature range of −40 °C to +60 °C
- 5% to 100% relative humidity, including condensing
- Blown and flying sand, dust, ballast, water, ice and other debris at velocities up to 125 mph (200 km/h)
- Combined vertical and horizontal movement incident to motion between vehicles
- Diesel fuel, car washing solvents and other fluids commonly experienced in the railroad environment
- Being dropped onto the ground or other hard surfaces occasionally, as might occur when applying or removing jumpers from a vehicle

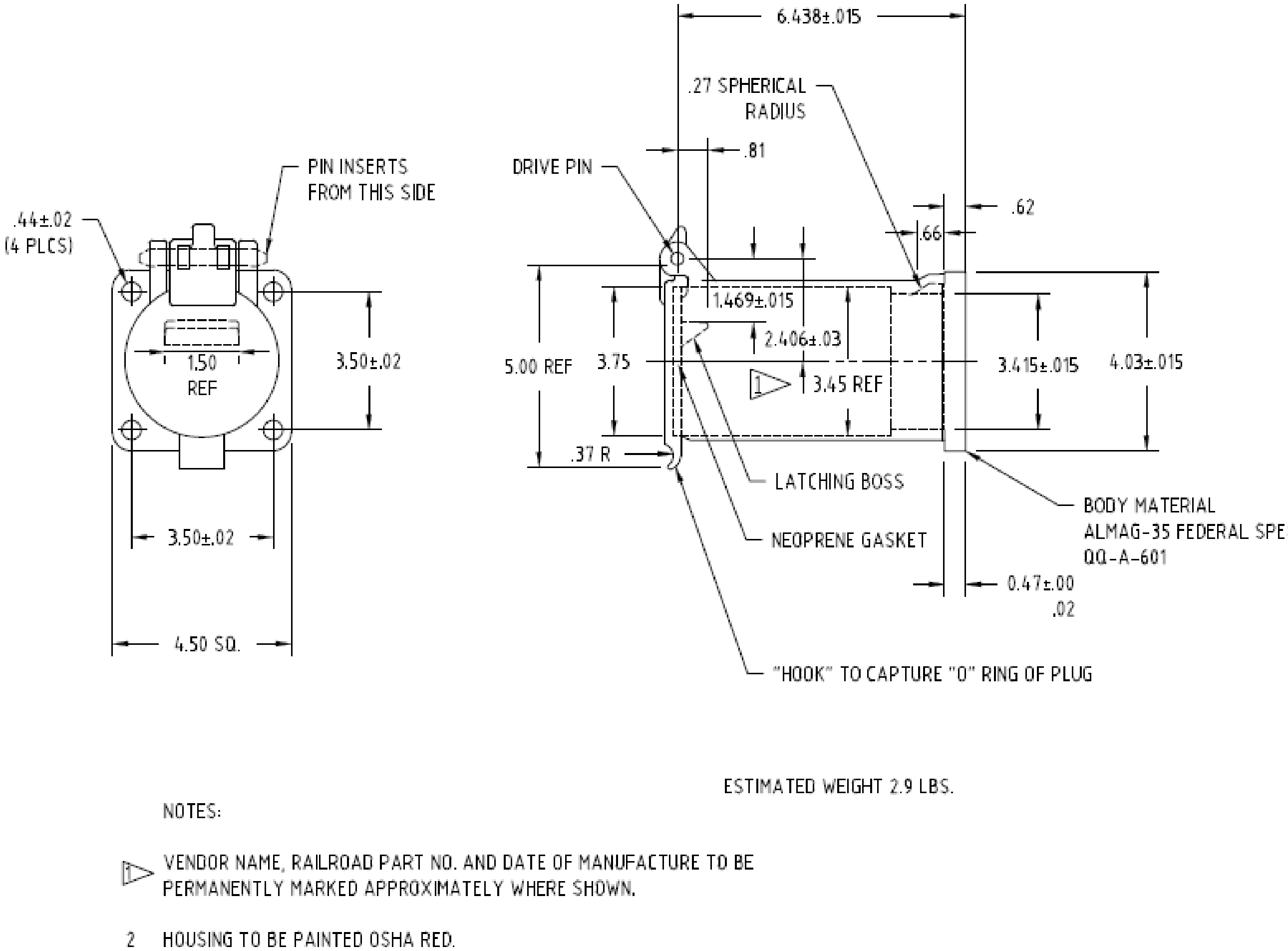
2. Receptacles

2.1 Housing and cover

2.1.1 Construction materials

The receptacle housing and its cover (**Figure 2**) should be made from a lightweight, corrosion-resistant material, aluminum alloy or approved equal. The cover spring and hinge pin should be corrosion-resistant, stainless steel or approved equal.

FIGURE 2
480 Vac, 400 A Receptacle Housing



2.1.2 Mechanical lock with connected plug

The hinged cover should be provided with a latching boss to hold a mated plug in a retained position.

2.1.3 Cover gasket

A neoprene gasket, secured with compatible adhesive, should be provided on the inside face of the cover to provide a weatherproof seal when the cover is closed.

2.1.4 Assembly color

The assembly should be painted red, preferably with polyester powder paint, in OSHA colors.

2.1.5 Warning label

The receptacle cover should be labeled as required in APTA PR-E-RP-016-99, "480 Vac Head End Power System," Section 2.3, unless otherwise required by the railroad.

2.2 Receptacle assembly

2.2.1 Assembly with conductors

The receptacle assembly (**Figure 3** and **Figure 4**) should consist of a receptacle body and contacts crimped to three 4/0 cables and each conductor of a three #10 conductor cord. Receptacle assemblies can be manufactured integrally molded or pre-molded, as described in the following sections.

FIGURE 3

480 Vac, 400 A Plug and Receptacle Interface

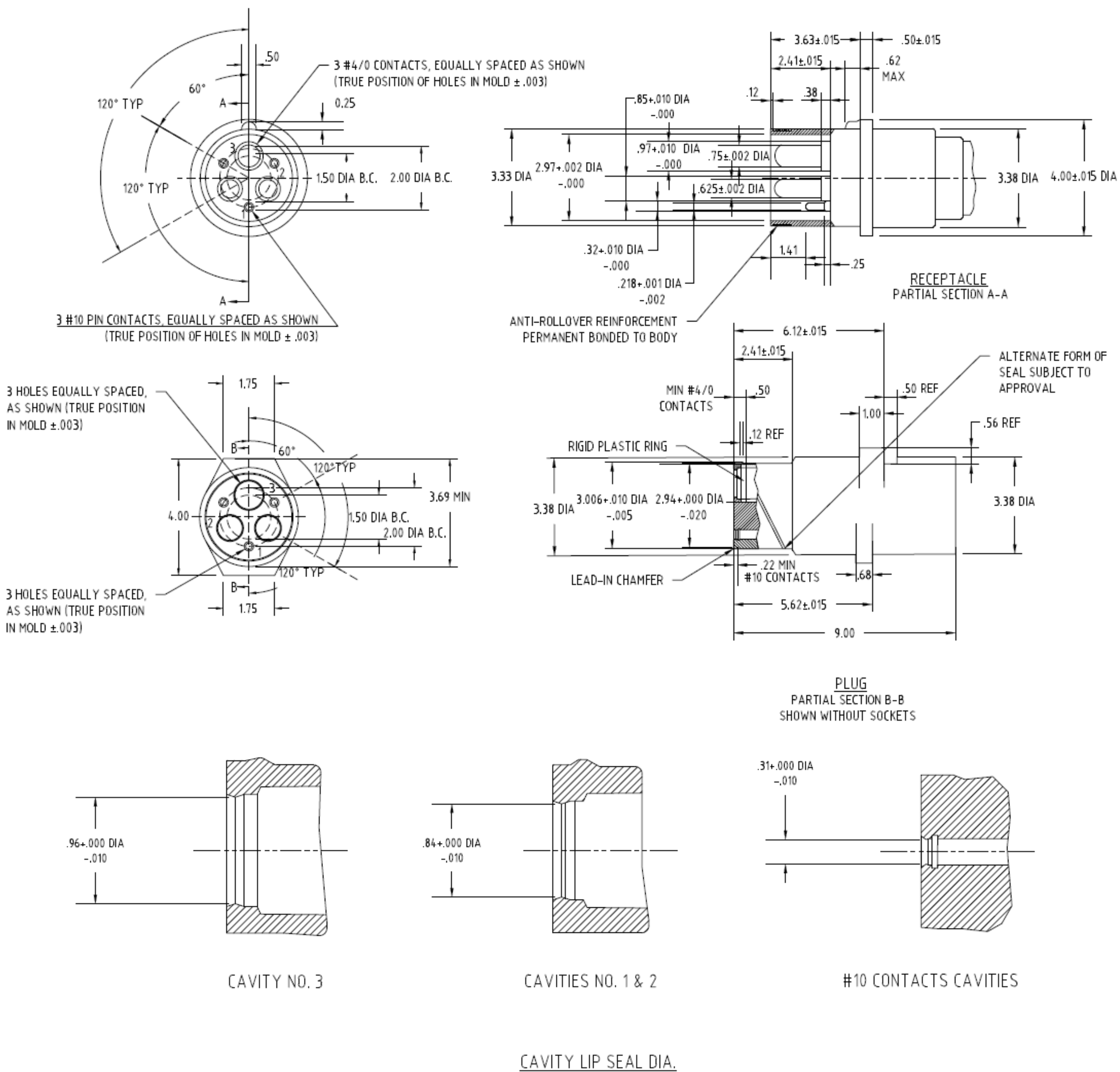
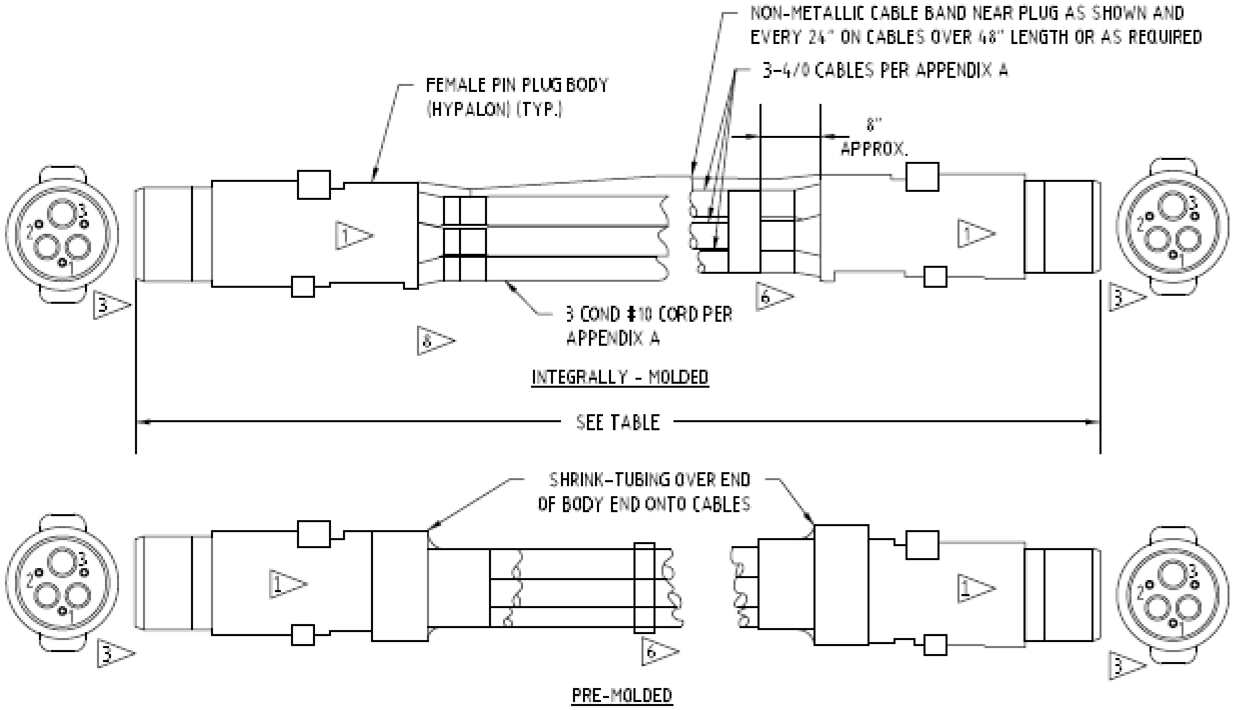


FIGURE 4

480 Vac, 400 A Receptacle Assembly



NOTES:

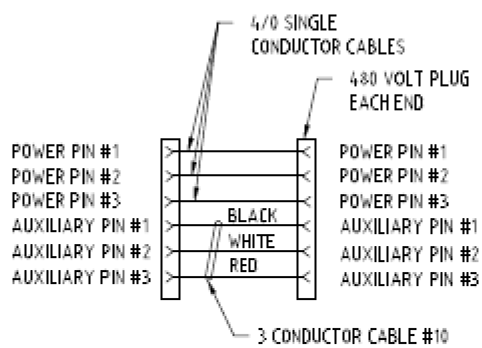
1. VENDOR NAME, RAILROAD PART NO. AND DATE OF MANUFACTURE TO BE PERMANENTLY MARKED APPROXIMATELY WHERE SHOWN.
2. MOLDED BODY TO BE YELLOW IN COLOR. 60–70 DUROMETER.
3. REFER TO FIGURE 3 FOR INTERFACE DIMENSIONS.
4. PHASE ROTATION 1,2,3
5. COLOR CODE OF 4/0 & #10 CONDUCTORS

   #1 BLACK
   #2 WHITE
   #3 RED

6. MINIMUM OF THREE WRAPS 1.50" WIDE PVC TAPE COLORED (OSHA COLORS) AS SHOWN ABOVE

YEAR ENDING IN	COLOR
1, 4, 7	BLUE
2, 5, 8	YELLOW
3, 6, 9	RED
0	GREEN

7. PROVIDE BLACK IN 3/C CORD FOR STRAIN RELIEF (CABLE TAKES STRAIN).
8. INDIVIDUAL #10 CONDUCTOR SHALL BE PROTECTED AGAINST PHYSICAL DAMAGE.
9. RAILROADS MAY SPECIFY OTHER LENGTHS.



JUMPER CABLE ASSEMBLY WIRING SCHEMATIC

ITEM	LENGTH
1	51" ± 1/2"
2	84" ± 1/2"
3	10" ± 1"
4	25" ± 2"
5	50" ± 2"
6	100" ± 2"

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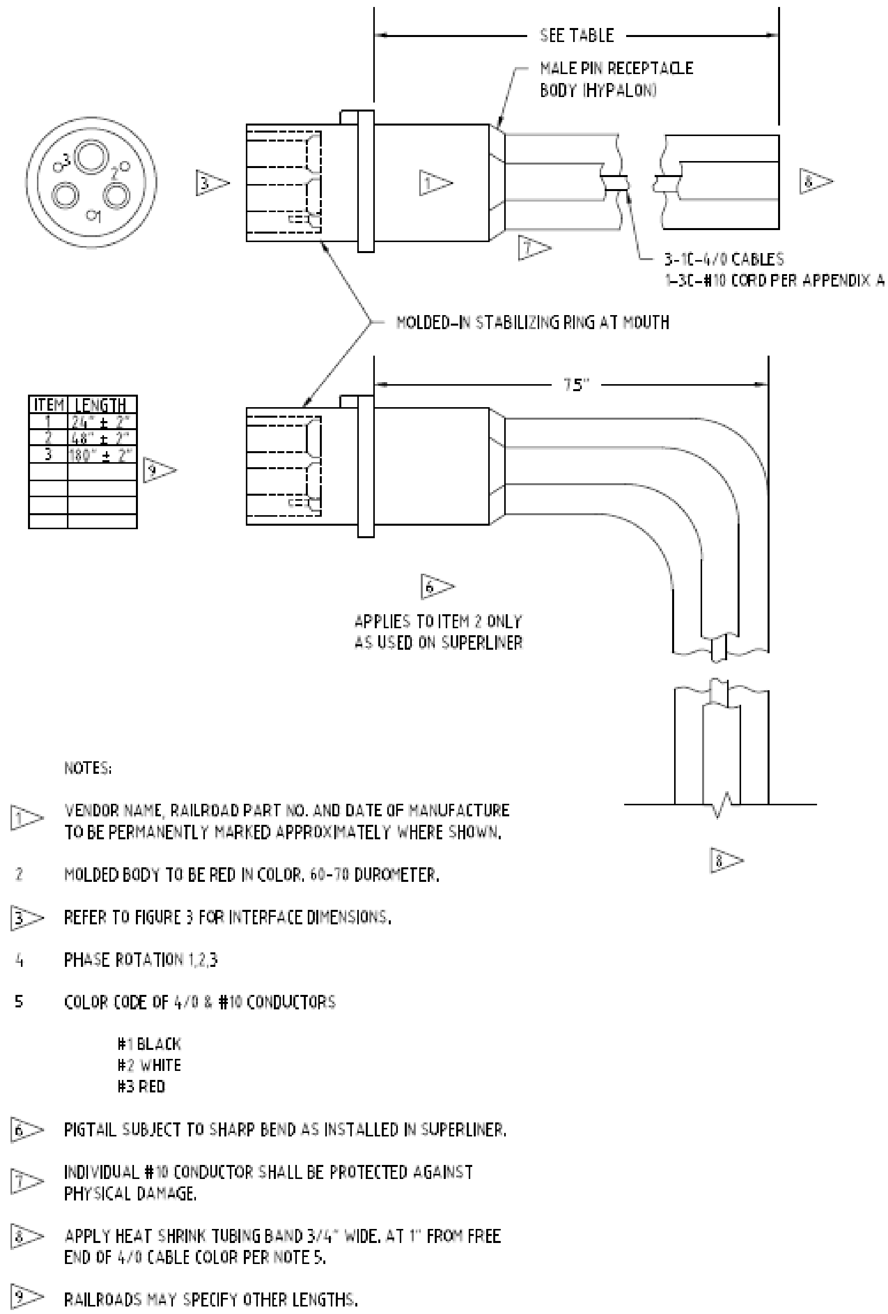
FIGURE 4 (cont.)
480 Vac, 400 A Receptacle Assembly



ITEM	LENGTH
1	24" ± 2"
2	48" ± 2"
3	180" ± 2"

2.2.1.1 Integrally molded

For integrally molded product, the individual contacts, crimped onto their respective cable/cord, are inserted into the body mold, the body elastomer is added, and this is then molded onto the contact assemblies. The fan-out of the three wires of the SO cord, between their contacts and end of SO jacket, shall be protected with an insulating sleeve, or equal, to prevent potential contact with the power contacts. This is to prevent possible shorts after the receptacle has been in service and has been subjected to flexing over the life of the product.

2.2.1.2 Pre-molded

For pre-molded product, the receptacle body is molded on its own, without contacts. The individual contacts, crimped onto their respective cable/cord are then inserted into the body, sealed and secured into position through the use of an encapsulating elastomeric potting material, poured in from the cable end of the body. The compound shall have the following properties:

- Dielectric strength of at least 950 V/mil
- Thermal conductivity of at least 0.48 W/mK
- Operating temperature range of −40 °C to +105 °C or better

The manufacturer must ensure that there are no internal voids or air gaps remaining after the potting process is complete.

2.2.2 Body material

The receptacle body should be made from a resilient material with mechanical properties equivalent to chlorosulfonated polyethylene rubber ("Hypalon"), red in color, capable of meeting the performance specified over a component operating temperature range of −40 °C to +60 °C.

2.2.3 Cable seal

Cable and cord entry into the body should be sealed to prevent entrance of water that may otherwise wick into the body from extended and repeated exposure to moisture: rain, ice or car wash chemicals.

2.2.4 Engaging reinforcement

The engaging end of the receptacle should be reinforced with a molded in stabilizing ring to resist buckling during engagement of plugs.

2.2.5 Manufacturer's mark and date

The body should be permanently marked with the manufacturer's name and date code (month and year, e.g., 1/25).

2.2.6 Contacts

Contacts should be copper alloy, 90% conductivity minimum, silver plated. Care should be taken during the molding process to provide the maximum possible clearance among the six circuits. Each contact should have a circumferential seal boot to achieve an interfacial seal between the receptacle contact and plug contact cavity while in the mated condition.

2.2.7 Contact retaining force

The 4/0 contacts should each be retained within the plug body while withstanding a pull-out or push-in force of 600 lb minimum, and the #10 contacts should each be retained within the plug body while withstanding a pull-out or push-in force of 150 lb minimum, relative to the plug body.

3. Jumper cable assemblies

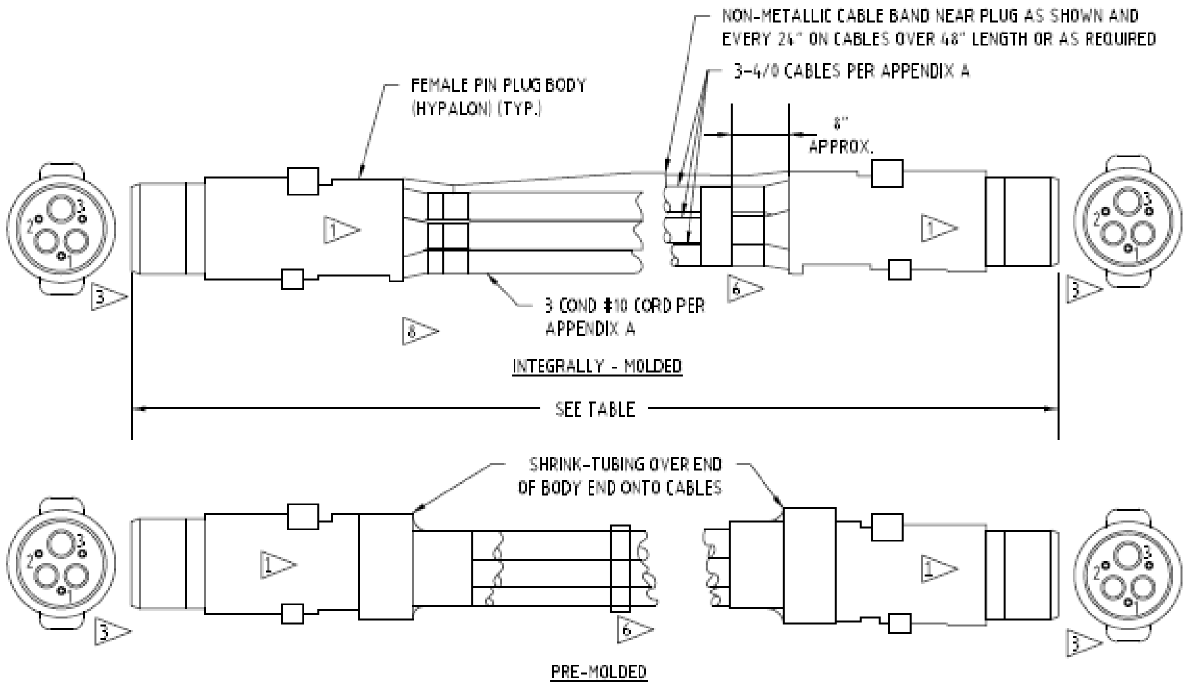
3.1 Portable jumper assemblies

3.1.1 Description of assembly

The portable jumper cable assembly (Figure 3 and Figure 5) should consist of two plug bodies and sets of contacts crimped to three 4/0 cables and each conductor of a #10 AWG three-conductor cord. Jumper cable assemblies can be manufactured integrally molded or pre-molded, as described in the following sections.

FIGURE 5

480 Vac, 400 A Portable Jumper Cable Assembly



NOTES:

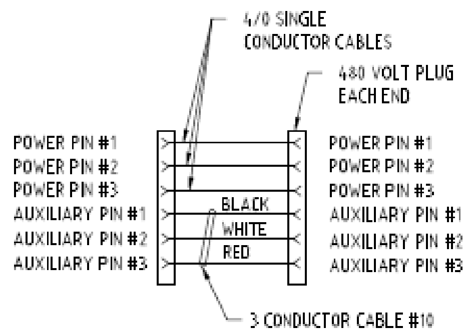
1. VENDOR NAME, RAILROAD PART NO. AND DATE OF MANUFACTURE TO BE PERMANENTLY MARKED APPROXIMATELY WHERE SHOWN.
2. MOLDED BODY TO BE YELLOW IN COLOR. 60–70 DUROMETER.
3. REFER TO FIGURE 3 FOR INTERFACE DIMENSIONS.
4. PHASE ROTATION 1,2,3
5. COLOR CODE OF 4/0 & #10 CONDUCTORS

   #1 BLACK
   #2 WHITE
   #3 RED

6. MINIMUM OF THREE WRAPS 1.50" WIDE PVC TAPE COLORED (OSHA COLORS) AS SHOWN ABOVE

YEAR ENDING IN	COLOR
1, 4, 7	BLUE
2, 5, 8	YELLOW
3, 6, 9	RED
0	GREEN

7. PROVIDE BLACK IN 3/C CORD FOR STRAIN RELIEF (CABLE TAKES STRAIN).
8. INDIVIDUAL #10 CONDUCTOR SHALL BE PROTECTED AGAINST PHYSICAL DAMAGE.
9. RAILROADS MAY SPECIFY OTHER LENGTHS.



JUMPER CABLE ASSEMBLY WIRING SCHEMATIC

ITEM	LENGTH
1	51" ± 1/2"
2	84" ± 1/2"
3	10" ± 1"
4	25" ± 2"
5	50" ± 2"
6	100" ± 2"

(9)

3.1.1.1 Integrally molded

For integrally molded product, the individual contacts, crimped onto their respective cable/cord, are inserted into the body mold, the body elastomer is added, and this is then molded onto the contact assemblies. The fan-out of the three wires of the SO cord, between their contacts and end of SO jacket, shall be protected with an insulating sleeve, or equal, to prevent potential contact with the power contacts. This is to prevent possible shorts after the jumper has been in service and has been subjected to flexing over the life of the product.

3.1.1.2 Pre-molded

For pre-molded product, the plug body is molded on its own, without contacts. The individual contacts, crimped onto their respective cable/cord, are then inserted into the body, sealed and secured into position through the use of an encapsulating elastomeric potting material, poured in from the cable end of the body. Heat shrink tubing should be applied over the rear of the body and onto the cables as a reinforcement.

The potting compound shall have the following properties:

- Dielectric strength of at least 950 V/mil
- Thermal conductivity of at least 0.48 W/mK
- Operating temperature range of −40 °C to +105 °C or better

The manufacturer must ensure that there are no internal voids or air gaps remaining after the potting process is complete.

3.1.2 Plug body material

The plug body should be made from a resilient material with mechanical properties equivalent to chlorosulfonated polyethylene rubber ("Hypalon"), yellow in color, capable of meeting the performance specified over a component operating temperature range of −40 °C to +120 °C.

3.1.3 Contact float

Contacts should "float" within the jumper head to accommodate any pin/socket misalignment and thus maintain reasonable mating forces.

3.1.4 Contact springs

A spring arrangement should be provided on each of the six female contacts to ensure reliable gripping action for the life of the jumper.

3.1.5 Contact material

Contacts should be copper alloy 90% conductivity minimum, silver-plated.

3.1.6 Contact insulation

Rigid insulation should be provided between the forward end of the socket contacts and the plug face to preclude any possible contact between any plug contact and any receptacle contact unless plugs and receptacles are properly aligned, such as might occur in standby wayside service operations.

3.1.7 Contact retaining force

The 4/0 contacts should each be retained within the plug body while withstanding a pull-out or push-in force of 600 lb minimum, and the #10 contacts should each be retained within the plug body while withstanding a pull-out or push-in force of 150 lb minimum, relative to the plug body.

3.1.8 Seals

The plug mating end should affect a circumferential seal in addition to the interfacial seal when mated with a receptacle.

Cable and cord entry into body should be sealed to prevent entrance of water that may otherwise wick into body from extended and repeated exposure to moisture: rain, snow, ice or car wash chemicals.

3.1.9 Cable lengths

The 3/10 cord (see **Figure 5**) should be 1 to 1.5 in. longer than the 4/0 cables, to prevent strain on the cord.

3.1.10 Manufacturer's mark and date

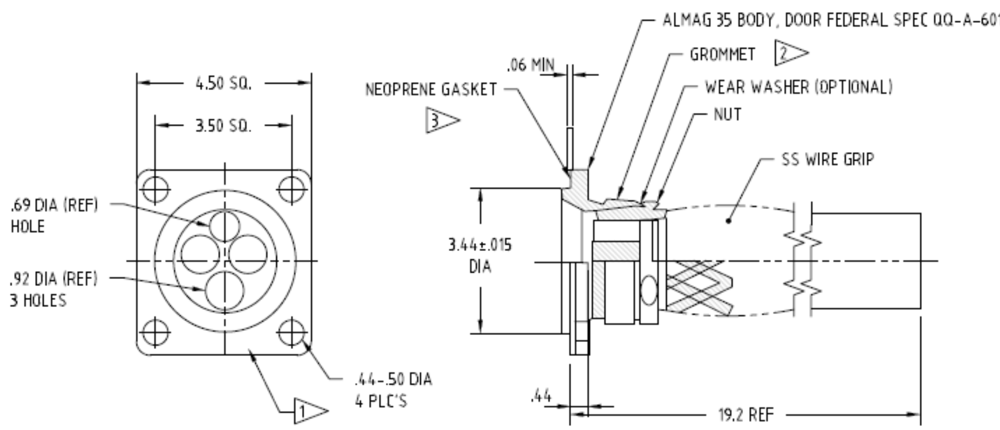
The body should be permanently marked with the manufacturers name and date code (month and year, e.g., 1/25) and the jumper should be color banded (see **Figure 5**).

3.2 Fixed jumper cable assembly

3.2.1 Description of assembly

The fixed jumper cable assembly (**Figure 3**, **Figure 6** and **Figure 7**) should consist of a plug body and contacts crimped to three 4/0 cables and each conductor of a #10 AWG three-conductor cord. The plug body and contacts, attached to one end, should be the same as supplied for portable jumpers described in sections 3.1.2 through 3.1.8. Jumper cable assemblies can be manufactured integrally molded or pre-molded.

FIGURE 6
Flange-Mounted Cable Grip, Fixed Jumper



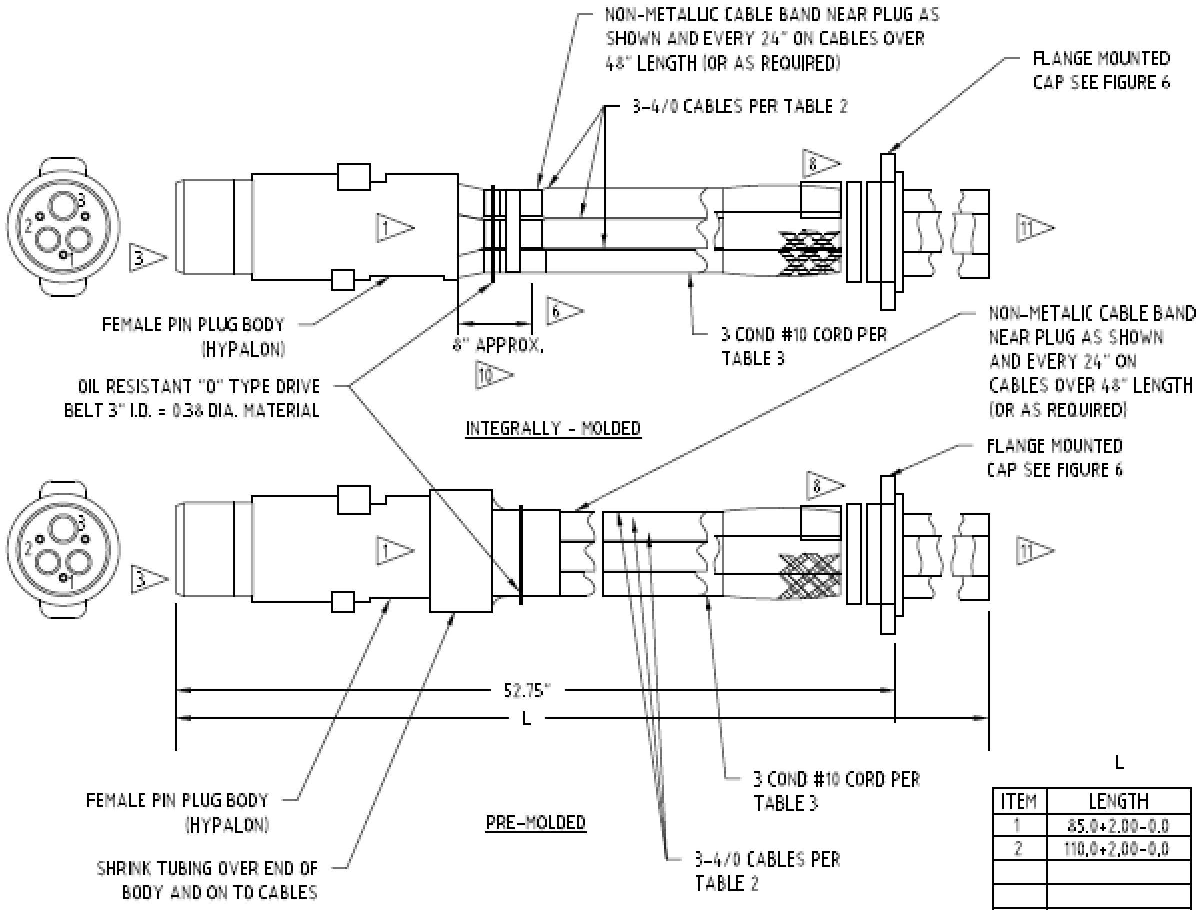
NOTES:

1. VENDOR NAME, RAILROAD PART NO. AND DATE OF MANUFACTURE TO BE PERMANENTLY MARKED APPROXIMATELY WHERE SHOWN.
2. WHEN INSTALLED, THE GROMMET MUST FORM A SEAL AGAINST 30 PSI BETWEEN ITSELF AND THE BODY, AS WELL AS ITSELF AND THE CABLES UTILIZED IN THE ASSEMBLIES SPECIFIED IN APPENDIX A.
3. FLANGE GASKET SHALL SEAL AGAINST 30 PSIG AIR PRESSURE.

ESTIMATED WEIGHT 1.5 LBS.

FIGURE 7

480 Vac, 400 A Fixed Jumper Cable Assembly



L

ITEM	LENGTH
1	85.0+2.00-0.0
2	110.0+2.00-0.0

NOTES:

1. VENDOR NAME, RAILROAD PART NO. AND DATE OF MANUFACTURE TO BE PERMANENTLY MARKED APPROXIMATELY WHERE SHOWN.
2. MOLDED BODY TO BE YELLOW IN COLOR. 60–70 DUROMETER.
3. REFER TO FIGURE 3 FOR INTERFACE DIMENSIONS.
4. PHASE ROTATION 1,2,3
5. COLOR CODE OF 4/0 & #10 CONDUCTORS

   #1 BLACK
   #2 WHITE
   #3 RED

6. MINIMUM OF THREE WRAPS 1.50" WIDE PVC TAPE COLORED (OSHA COLORS) AS SHOWN ABOVE

YEAR ENDING IN	COLOR
1, 4, 7	BLUE
2, 5, 8	YELLOW
3, 6, 9	RED
0	GREEN

7. PROVIDE BLACK IN 3/C CORD FOR STRAIN RELIEF (4/0 CABLE TAKES STRAIN)
8. APPLY WHITE TAPE OR HEAT SHRINK TUBING; TO BE FLUSH WITH GROMMET FACE WHEN CABLE LENGTH SET TO 52.75". SET CABLE & LENGTH & TIGHTEN FLANGE-MOUNTED GRIP FIRMLY.
9. INDIVIDUAL #10 CONDUCTOR SHALL BE PROTECTED AGAINST PHYSICAL DAMAGE
10. APPLY HEAT SHRINK TUBING BAND 3/4" WIDE AT 1" IN FROM FREE END OF 4/0 CABLE COLOR PER NOTE 5.
11. RAILROADS MAY SPECIFY OTHER LENGTHS.

3.2.2 Fixed end cable attachment

The cables should be secured to the vehicle through the Flange Mounted Cable Grip (**Figure 7**). It should consist of a flange with threaded body to accept a four-hole cable sealing grommet, grommet compression nut and stainless-steel cable grip. The flange portion should be provided with a sealing gasket. The compression nut should be secured against unintentional loosening through the use of a locking set screw or other approved means.

3.2.3 Cable lengths

The 3/10 cord (see **Figure 7**) should be 1 to 1.5 in. longer than the 4/0 cables to prevent strain on the cord.

3.2.4 Manufacturer's mark and date

The fixed jumper connector body should be marked with the manufacturer's name and date code (month and year, e.g., 1/25).

3.3 Adapter jumper cable assembly

3.3.1 Description of assembly

The adapter jumper cable assembly (**Figure 3** and **Figure 8**) should consist of a plug body with contacts and receptacle body with contacts crimped to three 4/0 cables and each conductor of a #10 AWG three-conductor cord. Jumper cable assemblies can be manufactured integrally molded or pre-molded. However, both receptacle end and plug end must use the same molding method. If pre-molded is selected, heat shrink tubing should be applied over the rear of the body of both plug and receptacle and onto the cables as a reinforcement.

3.3.2 Plug body and contacts

The plug body and contacts should be the same as supplied for portable jumpers described in Section 3.1.

3.3.3 Receptacle

The receptacle should be the same as supplied under Section 2.2.

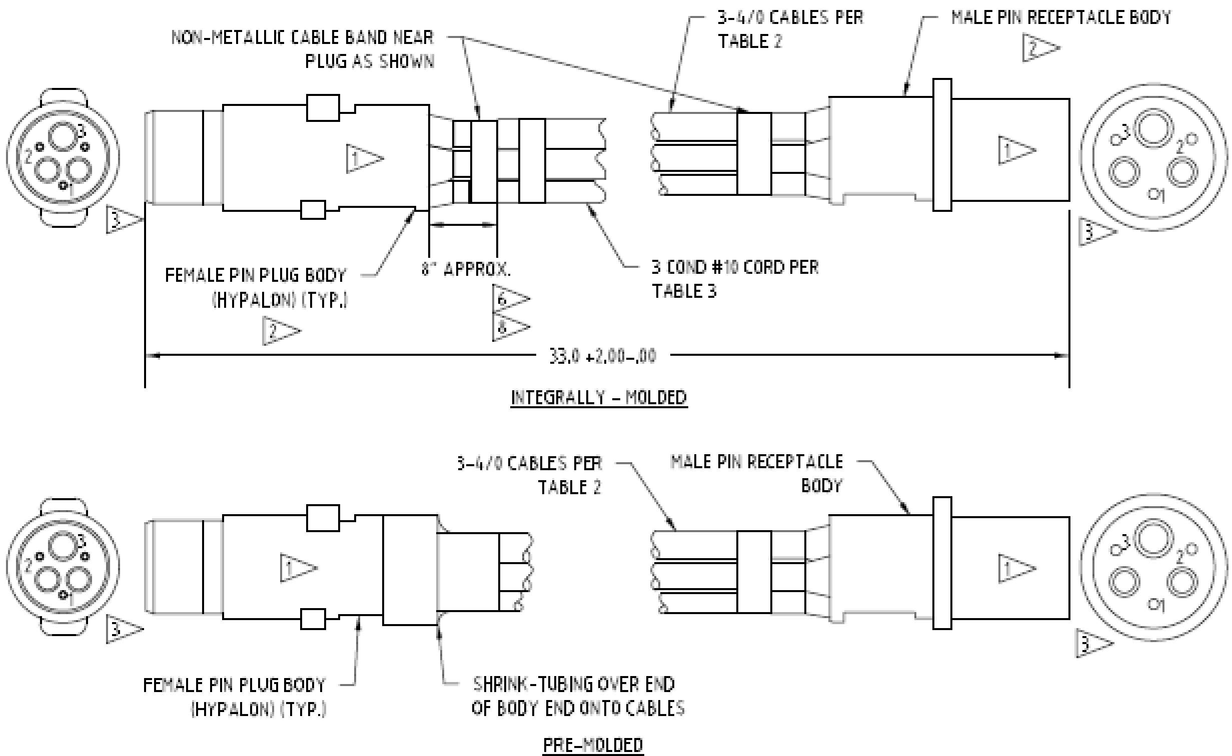
3.4 Looping jumper cable assembly

3.4.1 Description of assembly

The looping jumper cable (**Figure 9**) should consist of an integrally molded body at both ends connected with a #10 AWG three-conductor cord and a strain-relief cable. This jumper is used to close the TLC loop at the non-coupled end of a locomotive.

FIGURE 8

480 Vac, 400 A Adapter Jumper Cable Assembly



NOTES:

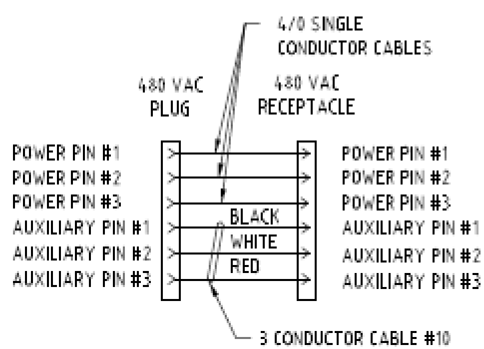
1. VENDOR NAME RAILROAD PART NO. AND DATE OF MANUFACTURE TO BE PERMANENTLY MARKED APPROXIMATELY WHERE SHOWN.
2. MOLDED BODY TO BE YELLOW IN COLOR. 60-70 DUROMETER.
3. REFER TO FIGURE 3 FOR INTERFACE DIMENSIONS.
4. PHASE ROTATION 1,2,3
5. COLOR CODE OF 4/0 & #10 CONDUCTORS

   #1 BLACK
   #2 WHITE
   #3 RED

6. MINIMUM OF THREE WRAPS 1.50" WIDE PVC TAPE COLORED (OSHA COLORS) AS SHOWN ABOVE

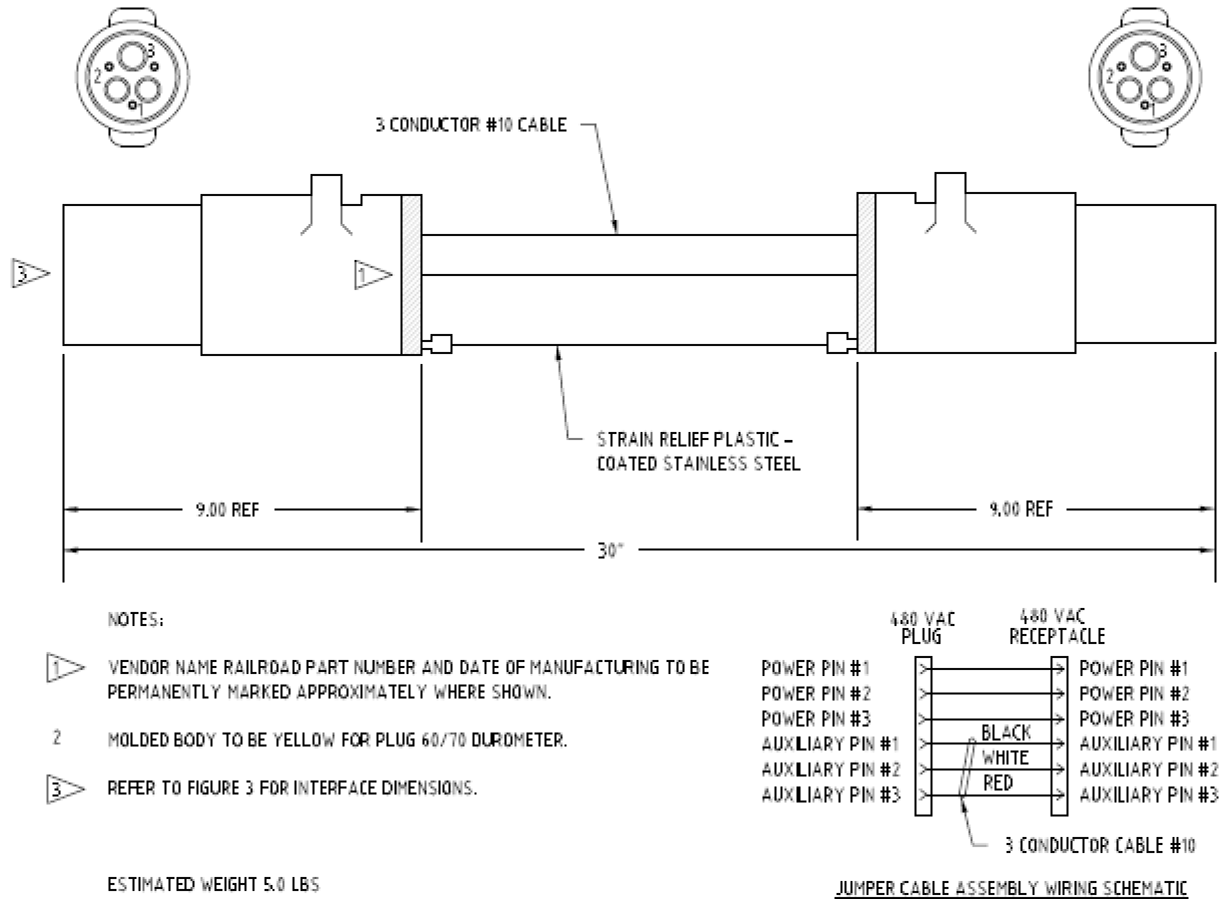
YEAR ENDING IN	COLOR
1, 4, 7	BLUE
2, 5, 8	YELLOW
3, 6, 9	RED
0	GREEN

7. PROVIDE BLACK IN 3/C CORD FOR STRAIN RELIEF (CABLE TAKES STRAIN)
8. INDIVIDUAL #10 CONDUCTOR SHALL BE PROTECTED AGAINST PHYSICAL DAMAGE.



JUMPER CABLE ASSEMBLY WIRING SCHEMATIC

FIGURE 9
480 Vac, 400 A Looping Jumper



3.4.2 Plug body and contacts

The plug body and contacts should be the same as supplied for portable jumpers described in Section 3.1.2. However, only the #10 contacts are required. A plastic-coated, stainless steel strain-relief cable should be provided between the two plug bodies.

3.4.3 Cable lengths

The 3/10 cord (see **Figure 9**) should be 1 to 1.5 in. longer than the strain-relief cable to prevent strain on the cord.

3.4.4 Manufacturer's mark and date

The fixed jumper connector body should be marked with the manufacturer's name and date code (month and year, e.g., 1/25).

3.5 Connector jumper

3.5.1 Description of assembly

The integrally molded connector jumper (**Figure 10**) should consist of a double-ended molded receptacle body with a durable plastic polarizing pin in the power pin #3 position, and only the #1 control pin connected.

The unused pin positions should be blank. This jumper is used on the wayside to provide a loop for the end of the train from which ground power is provided.

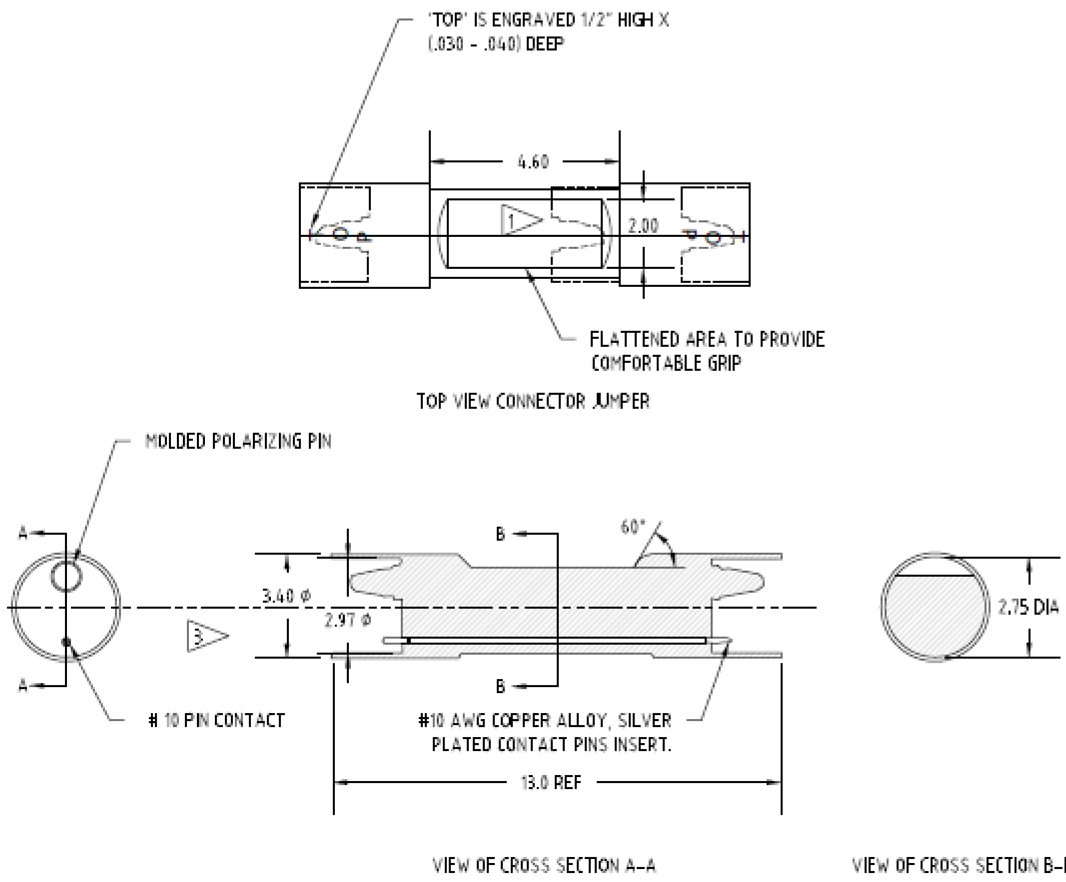
3.5.2 Receptacle body and contacts

The female portion of each receptacle body should be the same as supplied for the receptacle assembly as described in Section 2.2, except only the #1 control contact pin is required to provide continuity for the TLC circuit. The receptacle mouth should be reinforced to prevent rollover. The central portion of the body should be of smaller diameter and flattened to provide a convenient orientation and grip to the user.

3.5.3 Manufacturer's mark and date

The fixed jumper connector body should be marked with the manufacturer's name and date code (month and year, e.g., 1/25).

FIGURE 10
480 Vac Connector Jumper



4. Wire

4.1 Scope

This section defines the design and performance recommended practices for single conductor #4/0 AWG and three-conductor #10 AWG for head-end power cables rated 600 Vac, designed for heavy duty service where severe flexing is encountered. The design operating temperature range for this material is −55 °C to +90 °C.

4.2 Design characteristics and test methods

4.2.1 Conductor

The conductor should be bare or tinned annealed copper conforming to the requirements of ASTM B3 or ASTM B33, respectively. Stranding should be in accordance with ASTM B172 for Class M Rope-Lay conductor. Conductor should meet the dimensions and dc resistance specified in **Table 1**.

TABLE 1
Conductor Data

Conductor Size AWG	Coating	Area (cmil)	No./Size Each Wire in Strand	Strand Construction	Conductor Diameter (Max.)	Dc Resistance at 20 °C (Ω/mft)
4/0	Bare	211,600	5320/34	19 × 7 × 40/34	0.645 in.	0.0524
10	Tinned	10,380	259/34	7 × 37/34	0.132 in.	1.04

4.2.2 Primary insulation:

The primary insulation should be an approved single extrusion of thermoplastic elastomer (TPE) (or other material with equal or superior properties), specially compounded to have good electrical properties, flame resistance, excellent low temperature properties and extreme flexibility. The insulation should be tight fitting over the stranded conductors but should strip freely using manual mechanical stripping tools.

- **Thickness:** The average insulation wall thickness and minimum insulation thickness should be as specified in **Table 2** and **Table 3**.
- **Physical properties – unaged:** When tested according to UL Subject 62, paragraphs 86.1–89.19, the minimum acceptable values should be as follows:
  - **Tensile strength, min.:** 800 psi
  - **Elongation, min.:** 300%
- **Physical properties – aged:** When tested according to UL Subject 62, paragraphs 82.1–89.19, insulation samples that have been aged in a circulating air oven for 168 hours at 120 °C ±1 °C should retain the following minimum physical property values:
  - **Tensile strength:** 80% of unaged value
  - **Elongation:** 80% of unaged value

4.2.3 Reinforcement

A reinforcing seine twine or other approved material should be applied in the form of a cross-wrap over the primary insulation on the 4/0 cable.

4.2.4 Jacket

The jacket should be an approved black polychloroprene (neoprene), or other material with equal or superior properties, specially compounded for heavy-duty applications. The material should be compounded to exhibit excellent resistance to moisture, oils and fluids; abrasion; tearing; compression; flexing; ozone; sunlight; flame; and heat, as described in Section 1.2. The jacket should be extruded tightly over the primary insulation (and reinforcing twine), but adhesion between the two layers is not a requirement.

- **Thickness:** The average jacket thickness and minimum jacket thickness shall not be less than specified in **Table 2**.

- **Physical properties – unaged:** When tested according to Paragraph 6.4.14, ICEA S-19-81, the minimum acceptable values shall be as follows:
  - **Tensile strength, min.:** 1800 psi
  - **Elongation, min.:** 250%
- **Physical properties – aged:** When tested according to Paragraph 6.4.14, ICEA S-19-81, samples of the jacket material which have been aged in a circulating air oven for 168 hours at 100 °C +1 °C shall retain the following minimum physical property values:
  - **Tensile strength:** 50% of unaged value
  - **Elongation:** 50% of unaged value

TABLE 2

Dimensions for a Single Conductor #4/0 AWG

Conductor Diameter (Nominal)	0.605 in.
Average Insulation Thickness	0.060 in.
Minimum Insulation Thickness	0.054 in.
Average Jacket Thickness	0.085 in.
Minimum Jacket Thickness	0.068 in.
Cable Diameter	0.895 in. ±.025 in.

TABLE 3

Dimensions for Three Conductors #10 AWG

Conductor Diameter (Nominal)	0.132
Average Insulation Thickness	0.045 in.
Minimum Insulation Thickness	0.042 in.
Single Insulated Compound (Nominal)	0.229 in.
Fillers	Nylon filament as required to maintain circular cable cross-section
Binders	Mylar tape spirally applied 0.001 in. thick 25% min. overlap
Jacket Thickness	0.083 in. min.
Cable Diameter	0.685 in. ±0.015 in.
Color Code	Black, white, red

5. Acceptance tests on all receptacles and jumpers

5.1 Acceptance tests

Acceptance tests should-be conducted by the manufacturer on all receptacles and jumper cables as follows.

Tests should be conducted in accordance with the requirements of APTA PR-E-S-001-98, "Electrical Insulation Integrity," as well as the following, on each jumper and receptacle to ascertain:

- continuity
- freedom from unintended cross-connections
- hipot at 1960 Vac to housing and among conductors

Mechanical tests should be conducted on each jumper and receptacle to ascertain the following:

- plug/receptacle mating (to ensure proper alignment and operation of each contact)
- plug/receptacle mating force measurement (periodic sample only)
- gauging of each male contact OD
- check of "grip" of each female contact on male pin

6. Qualification tests

6.1 Listing of qualification tests

Qualification tests should be conducted on a minimum of six mated pairs of jumper/receptacles that should, as a minimum, demonstrate the following, in order:

1. Mechanical inspection (see Section 6.3.1)
2. Mating and unmating forces (see Section 6.3.2)
3. Insulation resistance (see Section 6.4.1)
4. Dielectric withstand voltage (dry) (see Section 6.4.2)
5. Physical shock tolerance (see Section 6.4.3)
6. Watertightness (see Section 6.4.4)
7. Dielectric withstand voltage (wet) (see Section 6.4.5)
8. Current rating/temperature rise (see Section 6.5.1)
9. Contact resistance (see Section 6.5.2)
10. Contact Retention Force (see Section 6.6.1)
11. Crimp Tensile Strength (see Section 6.6.2)
12. Sectioning (see Section 6.4.6)

6.2 Qualification test procedures

Prior to the first shipment, the railroad should be furnished with a minimum of six production quality test samples of each type for inspection and testing as described below.

There are three groups of tests:

- Mated pair durability/performance tests, conducted on six mated plug/receptacle pairs
- Contact rating and resistance tests, conducted on one mated plug/receptacle pair (may be conducted on one of the above six mated pairs or a separate mated pair)
- Contact retention and crimp tensile tests:
    - Retention test is a destructive test conducted on one plug and receptacle.
    - Crimp tensile test is a destructive test conducted on one of each type of contact.

6.3 Tests to be performed on all parts and assemblies of the quality test samples

6.3.1 Mechanical inspection

A mechanical inspection should be made to determine compliance with approved drawings, including a check of all dimensions and proper level of workmanship. This would include the use of metal go/no-go gauges to check plug sealing boss diameter (3.106 in. [78.89 mm]) and inside diameter of receptacle body.

6.3.2 Mating/unmating force

A check should be made to determine that the force necessary to mate and unmate plugs and receptacles is as stated in this recommended practice. Receptacles should be secured to the bench and plugs mated by hand, employing a slight rocking motion. A suitable force-measuring instrument connected to the receptacle should be used. Each of the plug/receptacle pairs should be mated three times each by three people (total of nine matings and readings). The test should be conducted at 70 °F (21 °C) on all six samples. In addition, the test should be conducted on one sample at 70 °F (21 °C) ambient, immediately after removing the sample from a freezer where it has undergone an eight-hour minimum cold soak at −20 °F (−29 °C).

6.4 Tests to be performed on six mated plug/receptacle pairs

6.4.1 Insulation resistance

Using a 1000 V megger or similar instrument, insulation resistance of the mated pair should be measured. Measurements should be taken between each contact and all other contacts and also between contacts and the housing. At 77 °F (25 °C), readings should be a minimum of 100 MΩ.

6.4.2 Dielectric withstand voltage (dry)

Each mated pair should be high potential tested at 1960 Vac for 1 minute. There should be no evidence of flashover or breakdown. Leakage current between any pair of contacts or between contacts and housing should not exceed 1 mA.

6.4.3 Physical shock tolerance

Six mated assemblies (less housings) should be subjected to a physical shock test by dropping the mated assembly onto a concrete surface from an elevation of 6 ft (1.8 m). Mated assemblies should be dropped in a horizontal position a total of eight times. Mating force measurements should again be taken per Section 6.3.2. There should be no change in the insertion and withdrawal force.

6.4.4 Watertightness

After the drop test is complete, the six mated assemblies should be immersed horizontally in 6 in. (150 mm) of tap water for 30 minutes to verify sealing between cable and connector body as well as primary and secondary sealing of the mated pair of connectors.

6.4.5 Dielectric withstand voltage (wet)

Following successful completion of the physical shock tolerance (Section 6.4.3) and watertightness (Section 6.4.4) tests, the assemblies should again be subjected to an insulation resistance test in accordance with Section 6.4.1 with the mated assemblies still immersed in water from the watertightness test. Readings to the housing are not required.

6.4.6 Sectioning

This procedure is used to verify uniformity of the body molding process as well as appropriate internal insulation. Details differ slightly for pre-molded vs integrally molded samples for the samples:

- **Pre-molded:** The six pre-molded sample plug and receptacle bodies will be sectioned into discs approximately 1 in. thick, as shown in **Figure 11** and **Figure 12**, to verify that there are no voids left from the molding or potting process.
- **Integrally molded:** The six integrally molded sample plug and receptacle bodies will be sectioned into discs approximately 1 in. thick, as shown in **Figure 11** and **Figure 12**, to verify that there are no voids left from the molding process and that correct spacing is maintained between power and control conductors where the wiring fans out from the rear of the contacts.

FIGURE 11
Sectioning of Receptacle

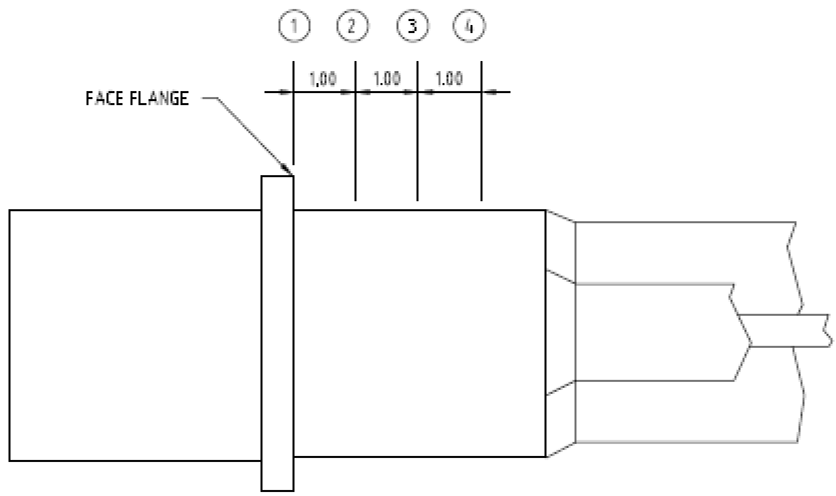
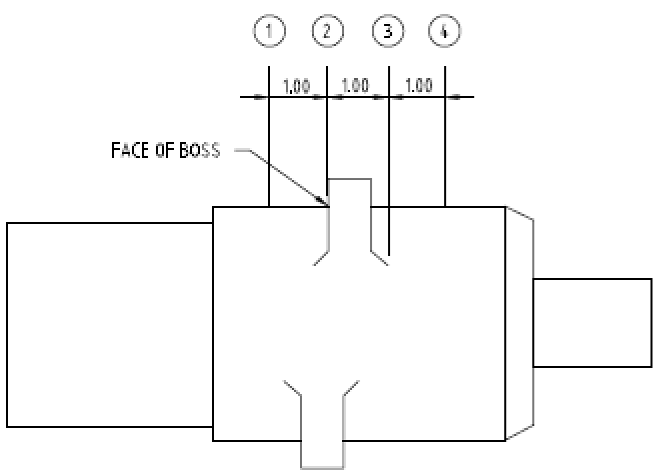


FIGURE 12
Sectioning of Plug



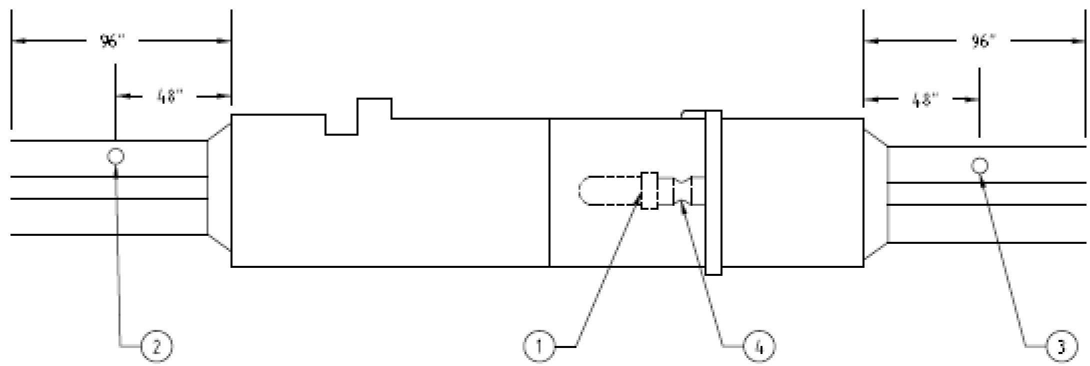
6.5 Tests to be performed on one mated plug/receptacle pair

The following groups of tests should be conducted on a single mated plug/receptacle pair. All tests defined in Section 6.3 should be completed prior to performing the following tests.

6.5.1 Current rating/temperature rise

A continuous dc current of 400 A should be applied simultaneously through each of the three power conductors. The mated assemblies (with the housing) should be supported in still air, 2 ft above floor level in a 110 °F (43 °C) ambient. Temperatures should be monitored by means of thermocouples as shown in **Figure 13**.

FIGURE 13
Temperature Rise Test – Location of Thermocouples



NOTES:

(1) WITHIN THE OUTLET BETWEEN THE INSULATION MATERIAL AND THE RECEPTACLE CONTACT AT A DEPTH OF APPROXIMATELY 2-1/2 INCHES, PIN #1 OR 2.

(2) AT THE SURFACE OF THE CABLE ASSEMBLY POWER CABLES APPROXIMATELY FOUR FEET FROM THE OUTLET.

(3) AT THE SURFACE OF ONE OF THE CABLE ASSEMBLY POWER CONDUCTORS (BENEATH THE INSULATION AND JACKET) APPROXIMATELY FOUR FEET FROM THE OUTLET.

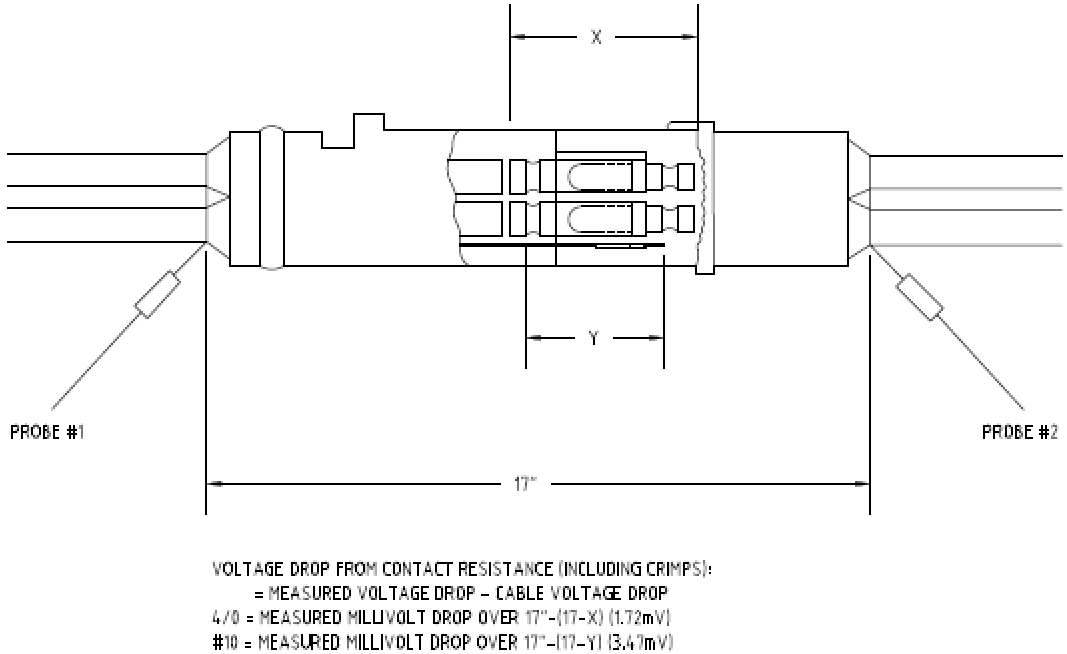
(4) AT THE JUNCTURE OF THE CRIMP WELL AND THE BODY OF THE A 4/0 SOCKET CONTACT, PIN #1 OR 2.

Temperatures should be continuously monitored and recorded at 30-minute intervals. Upon stabilization of all temperatures to within 1 °F (0.5 °C) over a 1-hour period, temperatures should be recorded at 3-minute intervals for 30 minutes. The cable assemblies would be considered acceptable if the temperature rises recorded in this test satisfactorily demonstrate to the railroad that continuous operation at 400 A in an ambient of 110 °F (43 °C) would not produce temperatures in excess of the insulation material's capability.

6.5.2 Contact resistance

The millivolt drop across mated male and female contacts including the cable crimps should be measured at rated current (400 A and 40 A respectively) to check that the voltage drop across the contact pair does not exceed 75 millivolts and 33 millivolts respectively for the 4/0 and #10 AWG cables. The test should be conducted at an ambient temperature in the range of 70 to 80 °F (21 to 27 °C). Refer to **Figure 14** for locations of the test probes. This test should be performed before and after the physical shock tolerance test described in Section 6.4.3. There should be no increase in the voltage drop as a result of the drop test.

FIGURE 14
Contact Resistance Millivolt Drop Test – Measurement Points



6.6 Tests to be performed on individual parts (to destruction)

The following two tests should be conducted to destruction of the parts. Parts used for Section 6.6.1 should first have passed the tests defined in sections 6.3.1 and 6.3.2. Parts used for Section 6.6.2 should be mechanically inspected and mated to determine that mating forces are reasonable (no instrumentation required).

6.6.1 Contact retention force

The contact pull-out and push-in forces should be measured for each contact type on the plug and receptacle body. Forces should meet or exceed those required in this recommended practice, applied at a rate of 1 in. ±¼ in. (25 mm ±6 mm) per minute.

The test should be continued until the part fails, or until the test machine capability is reached, whichever occurs first.

6.6.2 Crimp tensile strength

The minimum axial load to separate the wire from the contacts either by pulling the wire out of the wire barrel or breaking the wire within the wire barrel should be not less than shown in **Table 4**.

TABLE 4
Crimp Axial Loads

Contact Size	Axial Load
4/0	1200 lbf (5338 N)
10	150 lbf (667 N)

Representative contacts crimped to cable should be tested. The cable length should be sufficient for adapting to a Tinius Olsen or similar test device. The rate of applying the load should be 1 in. ±¼ in. (25 mm ±6 mm) per minute.

The test is to be continued until the part fails or the test machine capability is reached, whichever occurs first.

Related APTA standards

APTA PR-E-S-001-98, "Electrical Insulation Integrity"
APTA PR-E-RP-016-99, "480 Vac Head End Power System"

References

ASTM standards:

- B3, Standard Specification for Soft or Annealed Copper
- B33, Standard Specification for Tin-Coated Soft or Annealed Copper Wire for Electrical Purposes
- B172, Standard Specification for Rope-Lay-Stranded Copper Conductors Having Bunch-Stranded Members, for Electrical Conductors

ICEA S-19-81, Rubber-Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy

UL Subject 62, Thermoplastic Wire and Cable

Definitions

fixed jumper: A variation of a HEP jumper cable in which only one end is provided with a plug, while the remaining end is provided with a flange for mounting on a vehicle. This approach is taken to permanently affix the jumper to the vehicle and reduce the number of contacts, since they are present on only one end rather than two.

head end power (HEP): A system by which 480 Vac 3-phase electrical power, to operate auxiliaries, is provided to railroad vehicles from a central source via a trainline system. The power source can be locomotive (hence "head end"), power car or a wayside source.

HEP jumper cable: A cable assembly having the necessary power and control conductors and equipped with a plug on one or both ends, which is used to provide a flexible electrical connection between two cars and/ or locomotives or a wayside equipment.

HEP receptacles: The receptacles mounted on the ends of rail vehicles and wayside equipment into which the HEP jumper cables mate.

HEP trainline: An electrical cable system that allows HEP to be transmitted over the entire length of a train. It includes both power and control conductors. The trainline may provide power to equipment in each vehicle, or it may simply pass straight through, providing a power path between vehicles on opposite ends of that vehicle.

looping: The process of connecting a jumper cable between two adjacent receptacles (or a fixed jumper and adjacent receptacle) on the same vehicle. This is normally done on the exposed end of the first and last vehicles of a train and establishes the trainline complete circuit. Locomotives having the F-end HEP receptacles disconnected through the use of an isolation switch use an internal loop circuit and do not require an F-end loop.

> **NOTE:** When wayside power is applied via the end of the consist, the far end of the train is looped in the normal fashion. At the near end, a loop is put between left and right sides of the train, and the wayside power is connected with one jumper to the right and one jumper to the left side of the train.

portable jumper: A form of a HEP jumper cable in which both ends are provided with plugs. This approach is taken to allow the jumper cable to be easily removed from the vehicle and moved elsewhere.

Abbreviations and acronyms

Ω/mft	ohms per 1000 feet
A	amperes
cmil	circular mils
dc	direct current
DMU	diesel multiple unit
HEP	head end power
hipot	high potential
Hz	hertz
ICEA	Insulated Cable Engineers Association
lbf	pound-force
MΩ	megohms
mA	milliamperes
N	Newtons
OD	outer diameter
OSHA	Occupational Safety and Health Administration
psi	pounds per square inch
TLC	trainline complete
TPE	thermoplastic elastomer
UL	UL Solutions (formerly Underwriters Laboratories)
V	volts
Vac	volts alternating current
W/mK	watts per meter Kelvin

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