TECHNICAL SPECIFICATIONS

(TECHNICAL PROVISIONS)

SECTION TP08

MATERIALS AND WORKMANSHIP

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SECTION TP08
MATERIALS AND WORKMANSHIP

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TP08: MATERIALS AND WORKMANSHIP

The scope of the SFMTA LRV Doors and Steps Reconditioning and Systems Rehabilitation project is much narrower than a new LRV procurement, or entire vehicle overhaul, and many of the elements of this Materials and Workmanship section may not apply. However, the documentation has been provided as a guideline for the Contractor in the event that their chosen means of executing the specified tasks involves materials or construction methods not originally anticipated by SFMTA. Any CDRL listed in this section should only be submitted for elements of this project to which they apply, if at all.

The vehicles contain a variety of miscellaneous components including: labels, grommets, springs, gaskets, mounting hardware, captive screws, threaded fasteners, washers, lock washers, nuts, hangers, tape, tamper proof hardware, elastomeric components, seals, couplings, link pins and hook plates, vertical support rods/eye bolts; packing seals; springs, cotter pins, fuses, etc. Wherever such components are identified to be replaced, they shall be replaced in kind with new components. All new materials used in the work shall comply with the requirements of this section.

TP08.01 GENERAL

A. Overview

Inclusion of a material or method in this Section shall not necessarily indicate approval for application or use in a specific situation. Specific requirements detailed in applicable Technical Provisions shall take precedence. The most recent standards and specifications applicable at the time of issuance of the Notice to Proceed (NTP) shall apply unless otherwise approved by the Engineer

Surfaces exposed to passengers, crew, and maintenance personnel shall be kept smooth and free of burrs, sharp edges or corners, and dangerous protrusions. The rebuilt vehicle shall avoid pinch points, tripping hazards, snagging points, water traps, and debris accumulation points.

The Contractor shall ensure that any fastening or joining to structural members does not result in moisture accumulation within any structural member.

All materials shall withstand the environment in which the vehicle operates and the cleaning agents used without degraded performance, compromised functions, physical deformation or structural damage, and shall be inherently corrosion resistant, or be suitably finished with a corrosion resistant finish to minimize corrosion and degradation of appearance or function.

All materials utilized in the rebuild of the vehicle shall be subject to the approval of SFMTA.

As applicable, all materials shall comply with the Flammability, Smoke Emission and Toxicity requirements of this section.

B. Standards

The following domestic standards and specifications shall define the materials for this Contract: Federal or Military Specifications or Standards, the Specifications of the Aluminum Association of America, AAR, AISI, ANSI, ASME, ASTM, FRA, IEEE, APTA Standards and Recommended Practices for Rail Passenger Equipment, and others, as specified herein.

C. Prohibited Materials

The following materials shall be prohibited from use on the cars:

- PVC
- Asbestos
- Cadmium (except for battery)
- Lead, all applications including in paint and coatings, except for electronics solder
- PCBs
- Carcinogenic materials as listed by current Publication of the American Conference of Governmental Industrial Hygienists (ACGIH)
- All CFC and HCFC compounds
- Urethane foam
- Materials listed in 29 CFR Sec. 1910.9

D. Material Handling

The Contractor shall exercise care in the handling of all material used in the rebuild and overhaul of the SFMTA vehicle systems. Examples of mishandling material include but are not limited to the following:

- Exposure to corrosives or other elements that may deteriorate the subject material
- Inappropriate storage (stacking beyond packaged limits, careless placement of material, temperature extremes beyond the manufacturer's recommendations)
- Dragging materials across rough surfaces that may cause damage (e.g. dragging cables)
- Stretching materials during handling
- Exposure of certain materials to excessive UV light

TP08.02 JOINING AND FASTENING

A. Joining

1. General

Isolating and moisture-proofing materials, appropriate to the materials being joined, shall be employed at all times where these combinations exist.

2. Corrosion Control

Equipment located in areas highly susceptible to corrosion shall be made from inherently corrosion resistant material

Areas exposed to corrosive fluids, materials, or cleaning solutions shall be protected with coatings resistant to those fluids. Except as otherwise indicated, all aluminum exposed to view in finished work in the interior of the vehicle shall have a protective anodized coating.

The recommendations contained in "a Corrosion Control Manual for Rail Rapid Transit", UMTA-DC-06-0152-83-1, shall be used, except as otherwise directed by SFMTA.

3. Dissimilar Metal Treatment

All metals used in the fabrication process shall be surface treated with corrosion-resistant materials prior to assembly, with consideration being given to the severity of exposure to which the surface shall be subjected.

The joining of incompatible metals and materials shall be minimized as much as possible. When such metals must be joined, provision shall be made in accordance with MIL-STD-889 to prevent chemical reactions between the metals.

Surfaces of aluminum alloy parts secured to ferrous parts shall be protected with one-part polysulfide or non-corrosive silicone sealant used as joint compound, or with joint material that is non-hygroscopic and is free from chlorides and heavy metal ions.

Fibrous joint material shall be impregnated with bitumen or other water-repellant substance, which shall completely cover interfacing surfaces.

All ferrous metal surfaces, other than stainless steel, shall be protected by painting or zinc plating as defined in this specification, unless otherwise specified. Steel surfaces not requiring protection shall be galvanized by the methods and requirements described in ASTM A123. Minor damage to galvanized coatings shall be repaired with an approved zinc rich paint.

4. Joint Fitting

Joints shall be properly fitted. When not otherwise specified in Contractor drawings or specifications, gaps between joints shall be held to a dimension less than 10% of the thinner material being joined or 0.002 inch, whichever is greater. Gaps shall be uniform in width. Edges shall be free of burrs and sharp edges and shall have a smooth, finished appearance.

Where excessive gaps (greater than those permitted by approved drawings or standards) are found to exist at the faying surfaces of structural bolted or riveted connections, metal shims of the same material as that of the deficient part may be used, but only with the written approval of the Engineer. Shims, if used, shall be permanently fastened to one of the base parts being joined in a manner approved by the Engineer.

5. Metal-to-Metal Connections

Where metals contact each other, the contact surfaces shall be free of dirt, grease, rust, and scale. Unless specified otherwise, the contact surfaces shall be coated with a metal based primer which conforms to Society for Protective Coatings Specification SSPC-Paint 25. Metal primer may be omitted for austenitic stainless steel to austenitic stainless steel joints.

B. Fasteners

1. General

The Contractor and suppliers shall be responsible for selecting fastener types, sizes, styles, lengths, materials, grades, and finishes that will meet the requirements of the Technical Provisions. The Contractor shall minimize the number of different sizes and styles of fasteners used. Unless otherwise specified, screws, rivets, mounting bolts, or similar items shall be replaced in kind. Interior fasteners shall be countersunk where possible, or low profile heads shall be used where countersinking is not possible.

Fasteners exposed to public view shall be treated as follows:

- On the vehicle interior, all exposed fasteners shall be stainless steel (Grade 316), with flat or oval heads, properly countersunk.
- On the vehicle exterior, all exposed fasteners shall be stainless steel.
- Exposed screws shall be "Pin in Head" Torx tamper-resistant type and approved by the Engineer.

Threaded fasteners shall conform to current SAE J429 standards for externally threaded fasteners and SAE J995 standards for internally threaded fasteners. Steel fasteners ¼" diameter and above shall be SAE grade 5 minimum. For overhead and underfloor mounted equipment, the bolt diameter shall not be less than 3/8 inch.

Stainless steel fasteners shall be manufactured from austenitic stainless steel alloys, according to ASTM F 593, with a nominal tensile strength of 100 ksi.

All safety-related fasteners that are plated or chemically cleaned shall have certifications showing freedom from hydrogen embrittlement, based on a representative sample of the actual production fasteners which have been tested for hydrogen embrittlement by the OEM Contractor or a supplier following ASTM F519 procedures. An ASTM F606 wedge-test sample may be used in place of the ASTM F519 standard samples. Test loads shall be a minimum of 80% of yield strength or proof load and held for a minimum of 168 hours. Any failures shall reject the entire lot.

All bolts or rods passing through wood shall be coated with aluminum paint conforming to Federal Specification TT-P-38.

Use of self-tapping fasteners is prohibited, unless expressly approved by the Engineer.

Fasteners used throughout the car shall be inch-standard fasteners, except that ISO metric fasteners may be used in conformance with the requirements of this section.

When bolts are used to secure apparatus, where the bolt head is not accessible, a reusable mechanical locking device shall be used to prevent the bolt head from turning when the nut is being turned.

At least 1 1/2 full screw threads shall be visible beyond all nuts. When used without elastic stop nuts, bolts shall not project more than 1 1/2 full threads plus 1/4 inch for bolts, 1/4-inch diameter or less, and shall not project more than eight threads for larger diameter bolts, unless otherwise approved by the Engineer. With elastic stop nuts, bolt threads shall not project more than 1/4 inch, regardless of bolt size.

All-metal prevailing torque-type locknuts shall only be used where there is insufficient clearance to install ESNA type locknuts, or where the locknut is exposed to temperatures above 200 degrees Fahrenheit.

1. Threaded Fasteners

a. Inch-Standard Fasteners

All inch-standard threaded fasteners shall conform to ANSI B1.1 Standard, Unified Inch Screw Threads (UN and UNR Thread Form), or Industrial Fasteners Institute Fastener Standards.

Prevailing torque-type locknuts shall be nylon insert type, ESNA, or approved equal, conforming to IFI Fastener Standards or Military Standard MS-21044.

b. Metric Fasteners

Upon approval by the Engineer, specific Line Replacement Units (LRUs) that are supplied by a supplier or sub-supplier to the Contractor may be supplied with metric fasteners to ANSI B1.13M (ISO-metric) standards. All internal fasteners and threaded components of the approved unit shall have ISO-metric threads. Internal to components, there shall be no mixing of metric and inch-threaded fasteners. External mounting fasteners and threaded connecting components shall have ISO-inch threads to ANSI B1.1 Standards. Each unit, component, or group containing ISO-metric threads shall be indelibly identified in an approved manner and in a conspicuous approved location, to signify that the unit contains metric threaded fasteners. All repair and maintenance manuals shall be conspicuously marked to indicate where metric threaded fasteners are used within the unit.

Metric fasteners shall be marked as required in "Metric Fastener Standards," Industrial Fasteners Institute's latest edition.

2.

3. Torquing

All safety-related fasteners and all fasteners exposed to fatigue loads, shall be torqued to a minimum preload equal to 75% of their proof load and "torqued striped" after torquing by paint or other approved means. All other fasteners shall be torqued to a value appropriate to the application, so that they do not loosen in service.

4. Washers and Lock Washers

Washers shall be used under the heads of all bolts, screws and under all nuts. Washers shall ANSI B18.22.2 or ANSI B18.22M, latest revisions, as is appropriate for the application. Where high strength fasteners are applied, washers shall be hardened and comply with IFI Fastener Standards.

Lock washers, when applied, shall conform to IFI Fastener Standards. Lock washers shall not be used for fatigue applications where the fastener must be torqued and marked. If applicable, prevailing torque nuts shall be used for these applications.

5. Rivets and Lock Pins

Structural steel rivets shall conform to ASTM A 502 or American National Standard B 18.1.2 standards. Exposed heads shall be concentric with the shank and free from rings, fins, pits, and burrs.

Swage-locking (Huckbolt type) fasteners shall conform to Military Specification MIL-P-23469. All rough surfaces of the collar end of these fasteners shall be machined or ground smooth where accessible to passengers, crew, and maintenance personnel.

7. Plating of Fasteners

All carbon, alloy, and martensitic stainless steel fasteners shall be plated with zinc, unless specifically waived by the Engineer. Zinc plating shall conform to ASTM-B-633, Type II, and SC2, SC3, or SC4 or ASTM B695, Class 8, Type II. Cadmium plated fasteners shall not be permitted.

Grade 8, Metric 10.9, or stronger fasteners shall not be plated if the OEM finish is other than plating.

Regardless of the coating's propensity for hydrogen embrittlement, each lot of high strength fasteners, including OEM plated zinc or yellow bolts (Grade 5 or Metric Grade 8.8 or higher) shall be tested for hydrogen embrittlement. Each lot of lower strength fasteners shall be tested for hydrogen embrittlement if the coating has the possibility of causing hydrogen embrittlement.

8. Rivet and Bolt Holes

Rivet and bolt holes shall be accurately located, aligned, free of burrs and, when necessary, during assembly, holes shall be reamed round to specified size in position. Bolt hole clearances shall not exceed the Industrial Fasteners Institute's requirements. All removed and replaced rivets shall have the holes reamed to the size required such that the next larger rivet may be driven securely.

TP08.03 STAINLESS STEEL

A. General

Ferritic stainless steels shall be painted where exposed to passengers or the weather. Austenitic stainless steels may be unpainted. Unpainted stainless steels exposed to passengers shall be a single grade of austenitic stainless steel in which both the color and surface finish of abutting pieces shall match, except where the design specifically calls for contrasting appearance.

B. Austenitic Stainless Steel

Structural austenitic, stainless steel components assembled by fusion or resistance welding, shall be of AISI type 201L (UNS S20103), 301L (UNS S30103), 301LN (UNS S30153), or JIS SUS301L (with Nitrogen) and shall conform to the requirements of ASTM A 666, except that the carbon content shall not exceed 0.03% and the nitrogen content of type 301LN and SUS301L (with Nitrogen) shall not exceed 0.25%.

Stainless steel used in structural applications covered by the Technical Provisions shall also conform to APTA SS-C&S-004-98, *"Standard for Austenitic Stainless Steel for Railroad Passenger Equipment."*

Stainless steel to be used in structural applications shall be tested for susceptibility to intergranular corrosion in accordance with ASTM A 262, latest revision.

Ferritic stainless steel shall be used only with the specific written approval of the Engineer.

TP08.04 LOW-ALLOY, HIGH-TENSILE STEEL

A. General

Low Alloy High Tensile (LAHT) steel structural shapes, plates, and bars shall conform to the requirements of ASTM A 588, where available. General requirements for delivery of LAHT shapes, plates, and bars shall be as required by ASTM A 6.

Cold and hot rolled LAHT sheet and strip shall conform to the requirements of ASTM A 606, Type 4. General requirements for delivery of these products shall be as required by ASTM A 568.

Welded LAHT steel shall develop 15 ft-lbs Charpy V Notch impact strength in the CGHAZ (Coarse grain heat affected zone) 0.039 inches from fusion area at -20 degrees Fahrenheit.

TP08.05 STRUCTURAL CASTINGS

A. Repair Welding and Cast-Weld Design

Castings requiring repair or modification by welding after completion of heat treatment may be stress relieved locally by using electrically-controlled heating to a temperature not greater than 1,150 degrees Fahrenheit and slow cooling. Manual torch stress relief shall

not be permitted except for cosmetic welds and only then after the procedures have been submitted for review and approval. For cast-weld designs, the entire length of all assembly welds on any welded assembly of several separate castings selected for design qualification shall be radiographically inspected to ANSI/ASTM E 94 and E 142, using reference radiographs from the International Institute of Welding's *"Collection of Reference Radiographs of Welds,"* quality level Green. Portions of assembly welds stressed in tension by service loads shall meet quality level Blue.

No repair welding of stainless steel castings is permitted without express written approval of the Engineer.

TP08.06 ALUMINUM

A. General

Aluminum alloy mill products shall be identified by Unified Numbering System designations and shall conform to The Aluminum Association specifications contained in the Association's publication *"Aluminum Standards and Data."* Aluminum alloy castings used for door thresholds shall conform to ASTM B 26, B 85, or B 108 for, respectively, sand, die, or permanent mold castings, respectively. Aluminum alloy forgings shall conform to ASTM B 247.

B. Design Stresses

All aluminum structural members shall be designed so that calculated stresses under the specified AW3 passenger load do not exceed the allowable stresses per APTA SS-C&S-015-99, *"Standard for Aluminum Alloys for Passenger Equipment Car Body Construction".*

C. Fabrication and Fastening

The forming of aluminum parts, joining of parts by bolting, riveting, and welding, and the protection of contact surfaces shall conform to the requirements of the Aluminum Company of America's Technical Report Number 524, *"Specification Covering Use of Aluminum in Passenger Carrying Railway Vehicles,"* except as otherwise specified herein.

D. Protection of Contact Surfaces

Aluminum alloy surfaces shall not be secured to or make direct contact with the surfaces of copper, copper-bearing aluminum alloy, brass, bronze, silver, nickel, nickel alloys, nickel plated parts, lead, tin, or wood.

The contact surfaces of aluminum alloy with aluminum alloy shall be painted with zinc chromate primer or approved equal before securement.

The surfaces of aluminum alloy parts secured to steel parts, where exposed shall be protected with a one-part polysulphide sealant, zinc chromate paste, mica insulation joint material, or an approved equivalent material which completely covers the faying surfaces. The insulating material shall be non-hygroscopic, and, if fibrous, shall be impregnated with bitumen or an approved, non-corrosive, water- and moisture-repellant substance.

Stainless steel and carbon steel fasteners plated with zinc shall be coated with zinc chromate paste or approved equal before installation. Where possible, only the head and the shank of the bolt shall be in contact with the aluminum part when secured in place. Suitable bushings may be used in place of the zinc-chromate paste.

E. Interior Trim

Where unpainted aluminum is exposed to contact by passengers, it shall have a clear (natural) anodic finish. The finish process shall be the Aluminum Company of America's "Alumilite 204" with a minimum coating thickness of 0.0004 inch and a minimum coating weight of 21 mg/square inch, or approved equal process.

TP08.07 ELASTOMERS

A. General

Where a direct replacement part is not available, new elastomeric parts must meet the requirements of this section.

The elastomers shall have high resistance to ultraviolet radiation, weather, and all proposed car washing and other cleaning fluids. All elastomeric parts shall be resistant to ozone, oxidation, heat, oil, grease, and acid, and have the longest possible life consistent with the other characteristics specified.

All resilient mounts and elastomeric truck components shall be of natural rubber. Synthetic rubber compounds may be substituted for natural rubber only when approved by the Engineer for a specific application.

B.

Elastomer Test Requirements

Physical Property	Test Method	Test Value
Hardness	ASTM D2240	45 to 75, Durometer A
Tensile strength	ASTM D412	1500 psi
Ultimate elongation	ASTM D412	300%, min
Ozone resistance	ASTM D1149, Type A, 7 Days, Ozone concentration 100ppm, 104°F	No cracks under 7x magnification
Oil aging resistance	ASTM D471, Test oil/fuel shall be representative of application, 72 hours, 158°F	+30% maximum change in volume
Permanent-set resistance	ASTM D395, Method a or B	25% Maximum Set
Tear resistance	ASTM D624, Method B	300 lb/in
Brittleness temperature	ASTM D746	Brittleness temperature no greater than -40F
Resistance to heat aging	ASTM D573, 72 hours, 158°F	-30% change in elongation -15% change in tensile strength -5 to +15 change in hardness

C. Life Expectancy

For all parts made by vulcanizing an elastomer to metal, any premature failure (less than six years) between metal and the elastomer or in the elastomer, occurring when the parts are used in normal service shall be considered as having been caused by defect of materials or workmanship.

Door seals, door nosings, glazing rubber and gasket shall have a minimum service life of 10 years.

D. Metal Parts

Metal parts to which elastomeric material is vulcanized shall be made of SAE 1020 or 1045 hot-rolled steel, unless otherwise approved by the Engineer.

E. Bonding

The joining of elastomeric pieces shall be conducted by the hot vulcanization process. Bonding of elastomers by other processes shall not be allowed unless approved by the Engineer.

F. Truck Parts

Truck bumpers, snubbers, and the exterior surfaces of air springs shall be made of natural rubber or approved equal. They shall be compounded to be resistant to abrasion, oil, grease, and acid.

G. Seals

Glazing strips shall be of neoprene conforming to ASTM C 542, or approved equal material.

TP08.08 RUBBER FLOOR COVERING

A. General

Rubber floor covering shall contain a minimum of 38% (nominal, by weight of compound) Butadiene Styrene rubber, shall be non-staining, non-discoloring, and 100% non-oil extended. Only high quality, fine, hard clay shall be used as filler. No whitening (limestone) shall be used in the compound.

At 68 degrees Fahrenheit, the rubber flooring shall bend 180 degrees around a 3/4-inch diameter mandrel without breaking, cracking, crazing, or showing any change in color.

The rubber flooring material shall be fully homogeneous throughout and shall meet the requirements of ASTM F 1344.

Prior to the installation of the floor covering, any depressions, voids, or cracks in the sub-floor shall be filled and the sub-floor shall be leveled and smoothed with an Engineer approved leveling compound.

The coefficient of friction of the floor rubber shall not be less than 0.60 when tested to ASTM D 2047.

B. Inspection Criteria

This Section addresses defects that shall be cause for rejection, their allowable limits, and repair methods where repairs are permitted.

1. Thin-Skinned Blister

A thin-skinned blister is a blister which, when finger pushed, will collapse upon itself. Any thin-skinned blisters which exceed the limits listed below shall be cause for rejection of the floor sheet.

Maximum Size – 0.030-inch high, 0.80-square inch area with longest dimension of 2 inches.

Maximum Population – three blisters in a 12-inch x 12-inch area with only one other blister within 3 feet of this area.

Repair Method – using a hypodermic needle, apply just enough Super Bond 420 or Bostik 1685 or equivalent, compress the blister and bring to a flush surface.

2. Thick-Skinned Blister

A thick-skinned blister is a blister which, when finger-pushed, will collapse and then returns to its original condition.

Maximum Size – 0.030-inch high, 0.80-square inch area with longest dimension of 2 inches.

Maximum Population – three blisters in a 12-inch x 12-inch area, and only one other blister within 3 feet this area.

Repair Method – no repair authorized, not an acceptable condition.

3. Lump

A lump is a blister without a void, consisting of solid material.

Maximum Size – 0.030-inch high, 0.80-square inch area with longest dimension of 2 inches.

Maximum Population – three 12-inch x 12-inch area, and only one other lump within 3 feet of this area.

Repair Method – no repair required.

4. Hole

A hole is a defect which is 50% or more through the material. Any holes found in the floor sheet shall be cause for rejection of the sheet.

5. Thin Area

A thin area is a defect where the sheet is of reduced thickness locally.

Maximum Size – 0.030-inch deep at the lowest point, 3 square inches with the longest dimension of 5 inches.

Maximum Population – one thin area in a 40-inch x 40-inch area, and no other thin area within 3 feet of this area.

Repair Method – rub with #00 steel wool to blend this area into the normal thickness material and then buff to a normal surface finish.

TP08.09 FIBERGLASS-REINFORCED PLASTIC

A. General

Fiberglass-reinforced plastic (FRP) shall be a laminated material, consisting of a gel coated surface and a combination of reinforced fibers in a thermoset polymer resin matrix,

where the reinforcement has an aspect ratio that enables the transfer of load between fibers, and the fibers are chemically bonded to the resin.
An analysis shall be performed to confirm that the proposed construction method, glass content and laminate structure is adequate for its intended purpose and meets the strength requirements provided in the Technical Provisions.

FRP parts shall have a minimum thickness of 0.125 inch and shall have a greater thickness at attachment points and edges. If fasteners are used to attach and/or assemble FRP parts, the parts shall be reinforced in a manner approved by the Engineer to preclude the development of cracks. Exposed sharp edges shall not be allowed on any parts.

B. Construction

1. Resin

The resin shall be of good commercial grade, thermosetting, polyester, phenolic, vinyl-ester,, or, or acrylic material selected to meet the physical properties of the Technical Provisions and molding process requirements.

1. Reinforcement

The fiberglass reinforcement shall be mat, fabric, woven roving, continuous roving, spun roving, or swirl mat as required to meet the physical properties of the Technical Provisions and the molding process requirements. The proposed glass content shall be a minimum 20% by weight, and shall be confirmed through testing to ASTM D 2584.

2. Gel Coat

The gel coat shall be resistant to scuffing, fire, weather, and cleaning agents. The gel coat shall have a minimum thickness of 0.016 inch and a maximum thickness of 0.030 inch. If the surface of the FRP panel is to be painted, a primer gel coat shall be used and the part shall be painted in accordance Technical Provisions. If the FRP panel does not receive paint, then the gel coat shall be pigmented to match the car's color scheme.

Finished gel coated surfaces shall have a minimum gloss value of 85 when measured with a 60 degree glossometer and shall exhibit no print through of the reinforcements or have any appreciable orange peel.

3. Additives

Antimony trioxide is prohibited as a component.

4. Strength Requirements

Independent laboratory test reports of production items shall be provided confirming that the production reinforced plastic material complies with the requirements of the following standards. Test specimens shall be conditioned in accordance with ASTM D 618.

Mechanical Property	Test	Class I	Class II
Tensile Strength	D 638	10,000 lbf/in^2	18,000 lbf/in^2
Compressive Strength	D 695	18,000 lbf/in^2	24,000 lbf/in^2
Flexural Strength	D 790	15,000 lbf/in^2	30,000 lbf/in^2
Impact Strength	D 256	10 foot pounds per inch of notch	13 foot pounds per inch of notch
Hardness		45 Barcol	45 Barcol

Class I: Items which are non-structural or will not be exposed to any loads such as window masks, destination sign shrouds, ceiling cove panels, ceiling headers, etc.

Class II: Items which are structural or will be exposed to loads from passengers or impacts such as end bonnets, under floor equipment enclosures, door pocket panels, wainscot panels, toilet room modules, toilet shrouds, passenger seat back shrouds, windscreens, stair wells, etc.

TP08.10 THERMOPLASTIC SHEET

A. General

Thermoplastic sheet shall be used as extruded or vacuum-formed and shall not contain plasticizers in polymer blend.

Thermoplastic sheet shall be homogeneous and extruded from virgin stock which does not include any regrind of vacuum formed parts. The applicable ASTM procedure shall be used to measure each of the characteristics. Only UV stabilized pigments shall be used to create the specified color of the thermoplastic sheet.

B. Quality

The finished parts shall be free of waves and quilting on both sides. Degraded polymer in the sheet shall not be allowed. Voids, lumps, and contamination shall be cause for rejection of parts.

C. Strength Requirements

Independent laboratory test certificates shall be provided stating that the thermoplastic sheet complies with the requirements of the following standards. Extruded sheet in the surface finish specified shall be used for testing.

Mechanical Properties	ASTM Method	Value
Specific Gravity	D 792	1.20 to 1.45
Tensile Strength	D 638	5,500 lbf/in^2 minimum
Elongation	D 638	50%
Flexural Strength	D 790	8,000 lbf/in^2 minimum
Flexural Modulus	D 790	3.3 x 105 lbf/in^2
Hardness Rockwell "R" Scale	D 785	90 to 110
Heat Shrinkage - 15 minutes at 350 degrees Fahrenheit		10% maximum in machine direction 5% maximum in transverse direction
Heat Deflection (annealed) @ 264 lbf/in^2	D 648	165 degrees Fahrenheit minimum
Impact Strength Fabricated Parts Gardener Dart Drop 0.5-inch diameter ball: at 73 degrees Fahrenheit at -20 degrees Fahrenheit	D 3029	 320 in-lb minimum 80 in-lb minimum

TP08.11 PIPING AND TUBING

A. General

All piping valves, fittings, installation methods, and testing shall be in accordance with the Code for Pressure Piping, ANSI B31.1. All joints shall be easily accessible.

Air or hydraulic hose applications shall not be permitted in locations where adequate visual inspections cannot be made. Hose installations shall be arranged in such a manner as to prevent accidental cross connections to other hoses located in the same general area.

Hose installations shall be such that kinking, rubbing, straining, and unnecessary swinging are precluded. Routing that requires other piping, or cables, as the sole means of support shall not be accepted.

All piping systems shall be cleaned to remove dirt, metal chips, oily contamination, and moisture. After full installation on the vehicle, and before connection or installation of system components, the piping system shall be completely flushed with a suitable liquid solution, using appropriate pressure and velocity to fully dissolve all contaminants from manufacture and installation.

Following installation, piping systems shall be pressure tested in accordance with ASME B31.1 or other approved method. All leaks shall be repaired to the Authorities' approval

and re-tested until acceptable under the approved test criteria.

The Contractor shall perform a leak test on the final air or hydraulic piping system, with all components installed, on each vehicle in accordance with IEC 61133. The Contractor shall submit a copy of the test procedure for approval. A copy of the test report for each vehicle, including retest reports if appropriate, shall be included with each Vehicle History Book.

Pipe routing and support shall keep the total length and number of fittings and bends to a minimum. The minimum clearance of ⅛ inch shall be maintained on all piping and tubing. Joints that serve the sole purpose of connecting straight runs of pipe shall not be used. Unavoidable joints in piping shall be made in an approved manner. All inaccessible runs of tubing or piping shall be without joints.

Piping and tubing shall be adequately supported at least every 24 inches throughout its length and at connections, and must not interfere with the removal of or access to other components. At all locations where pipe or tubing passes through holes in the floor, bulkheads, structure, or any fixed member, it shall be rigidly clamped to protect against possible damage or noise due to bearing, abrasion, or car dynamics-induced rattling. Clamps shall not be welded, brazed or otherwise permanently fastened to any pipe or tubing. Pipe and tubing interfaces with clamps shall be insulated with an elastomeric material to protect and sound-insulate the pipe or tubing.

Wherever piping interfaces with vibration-isolated rotating equipment approved flexible vibration eliminators shall be used. The pipe connection at either end of the flexible elements shall be rigidly clamped. All pipe clamps shall be inherently rigid and shall be firmly attached to car structure. All clamps shall be of a suitable material for the application.

B. Air Piping, Tubing, and Fittings

All piping shall be seamless stainless steel per ASTM A269, or carbon steel per ASTM A822, as determined by the application.

Stainless steel fittings must be used with stainless steel piping and tubing. Forged steel fittings, zinc plated to ASTM B633, Type II, Yellow, SC3 / SC4, may be substituted upon Authority approval. Forged steel fittings, zinc plated to ASTM B633, Type II, Yellow, SC3 / SC4, shall be used with carbon steel tubing.

Type "K" annealed copper tube per ASTM B88, latest revision, may also be used, when specifically approved by the Engineer.

All air piping must comply in all respects with the brake supplier's design and installation requirements. The diameter of the main reservoir pipe and brake pipes shall meet the brake supplier's requirements. All air pipes shall be sized in accordance with the function intended.

All hoses used shall comply with AAR M-618. All hose fittings shall be of an approved reusable type.

All piping shall be installed in accordance with AAR 2518 as incorporated in Standard S-400 (AAR Manual E) and in such a manner as to provide drainage to prevent freezing.

C. Brazing and Soldering of Piping, Tubing, and Fittings

All brazing and soldering shall comply with the applicable parts of Technical Provisions

TP08.12 PRESSURE VESSELS

All pressure vessels shall conform to the latest revision of Section VIII of the ASME Boiler and Pressure Vessel Code for Unfired Pressure Vessels.

TP08.13 WIRE AND CABLE

A. General

Selection of wire sizes and insulations shall be based on the current-carrying capacity, voltage drop, mechanical strength, temperature, and flexibility requirements in accordance with applicable AAR, APTA, ICEA, ASTM, NEC, NFPA 70, and MIL Specifications,and these Technical Provisions.

All wire and cable shall comply with the flammability, smoke generation and toxicity requirements of this section.

The use of solid wire shall not be permitted. Extra-fine wire stranding shall be utilized on applications subject to repetitive motion.

Leakage between primary wiring and vehicle body shall be measured in accordance with IEEE 11. The resistance shall be at least 10 MOhms when measured with 1,000-volt megOhmeter.

Hi-Pot shall be accomplished on all primary power wiring at 2,500 VAC for 1 minute per IEEE 11.

B. Conductors

Conductors for irradiated, cross-linked polyolefin wire shall be soft, annealed tinned copper in accordance with ASTM B33. Minimum stranding shall conform to AAR Standard S501, S502 (Number 589), or ASTM B-172 Class K, or ICEA S-66-524/Nema WC7, Table L-7, Class K for AWG No. 10 or larger, as appropriate for the application.

Stranding and conductor construction for wire sizes AWG No. 12 to AWG No. 16 shall be in accordance with ASTM B-174, Class K, or ICEA S-66-524, Table L-8, Class M, as appropriate for the application.

Stranding and conductor construction for wire sizes AWG No. 18 and smaller shall be in accordance with ASTM B-174 Class L or ICEA S-19-81, Table L-8, Class M, or shall be 19-strand construction as appropriate for the wire size.

C. Insulation

1. General Wiring Insulation

For all general car body wiring, the insulation shall be a flame retardant, flexible, irradiated cross-linked polyolefin material having a continuous temperature rating of 230 degrees Fahrenheit. The insulation shall be rated at 2,000 V, AC and dc, in the case of wires carrying a nominal voltage greater than 150 V AC or dc, and rated at 600 V, AC and dc, in the case of wires carrying a nominal voltage of 150 V or less, AC or dc. For wire sizes AWG No. 6 and larger, the insulation material shall be formulated for extra flexibility.

Flexibility for cable sizes up to AWG No. 2/0 shall comply with AAR RP-585, paragraph 5.9.7.1, for the appropriate wire size.

Flexibility for cable sizes AWG No. 2/0 and larger shall comply with AAR RP-585, paragraph 5.9.7.

Cross-linked polyolefin insulation shall not be permitted for use on wires connected to heater

2. Wire Insulation for High Temperature Applications

Teflon, mineral-filled, abrasion-resistant insulation may be used on wire sizes AWG No. 12 to AWG No. 28. High temperature insulation shall be used where wiring is connected to heat-generating apparatus, where the ambient temperature can exceed 257 degrees Fahrenheit (125 degrees Celsius), or where Teflon is specified as a requirement. The insulation shall be rated at 1,000 V, AC and dc, in the case of wires carrying a nominal voltage greater than 150 V, AC or dc, and rated at 600 V, AC and dc, in the case of wires carrying a nominal voltage equal to or less than 150 V, AC or dc. The insulation shall have a continuous temperature rating of 302 degrees Fahrenheit (150 degrees Celsius) or greater and shall be in accordance with the following requirements:

For wire sizes AWG No. 16 and larger: abrasion resistant Teflon (Polytetrafluorethylene – PTFE) meeting MIL-W-22759/6B or 10B, as appropriate for the voltage level used, or silicone rubber meeting AAR RP-587C. Conductors for high temperature wire AWG No. 12 and smaller shall be soft, annealed nickel-plated copper constructed in accordance with MIL-W-22759/6B.

For wire sizes AWG No. 18 and smaller: abrasion resistant Teflon (PTFE) meeting MIL-W-22759/6B or 10B, as appropriate. When used for interconnecting of apparatus, this type wire shall be in bundles with a protective covering of high temperature-rated, low smoke-generating insulation.

No high temperature insulated wire shall be used in conduit or raceways without specific approval. The Contractor shall submit all applications of high temperature wire insulation for review and approval.

3. Wire Insulation within Equipment

Insulation on wiring within replaceable modular units, electronic apparatus such as cards and card racks, and other equipment, as approved, shall be Tefzel (Ethylenetetrafluoroethylene – ETFE) per ASTM D 3159, and insulation construction per Military Specification MIL-W-22759/16 (AS), irradiated cross-linked polyolefin or Teflon (Polytetra-fluorethylene – PTFE) type EE, per Military Specification MIL-W-16878/5.

4. Wire Insulation in Crowded Locations

Wire for connections locations where there are crowded concentrations of low voltage control wiring, may be insulated with Tefzel (ETFE) per ASTM D 3159 and insulation construction per Military Specification MIL-W-22759/16 (AS), except that the wall thickness shall be 0.025 inch. When used for this application, wires shall be bundled with a protective covering of irradiated, cross linked modified polyolefin insulation.

D. Multi-Conductor Cables

1. General

For high-temperature applications, the cable shall conform to MIL-C-27072, with Type V connectors, Style 4 sheaths, Class D jackets, if needed, and shields, if needed. All conductors in multi-conductor cables shall be color coded or otherwise permanently identified as approved. In applications where current is not a factor in wire size selection, AWG No. 16 may be used between repeater devices and displays. For multi-conductor cables carrying low-voltage, high-speed, serial data, exceptions to the wiring requirements may be submitted for approval, based upon availability of wire to meet the application requirements.

2. Fillers

Where required to obtain a circular cross-section, fillers shall be made of non-hygroscopic materials compatible with the wire insulation and jacket, and shall be of the same or of a higher temperature rating than the wire insulation.

3. Tape

The binder tape material shall be non-hygroscopic and shall be of the same (or better) temperature class as the wire insulation, and shall be of a compatible material.

4. Shield

The shield shall consist of either tin-plated copper braid, concentrically-served copper, or aluminum/polyester tape with a drain wire, as appropriate for the application. The shields shall have the following minimum properties:

- Copper shield shall be made of either tinned, coated copper strands which conform to ASTM B 33, or silver-coated copper strands which conform to ASTM B 298, as is appropriate for the wire insulation. Shield coverage shall not be less than 85%. Shield strand size and application shall not be smaller than AWG No. 38.

- Aluminum/polyester tape shields shall consist of a helical wrap of aluminum/polyester tape with a nominal thickness of 0.0004-inch aluminum on a backing of 0.001-inch polyester. The tape shall have a minimum overlap of 10% of the tape width to ensure complete coverage. In contact with the aluminum side of the shielding tape shall be AWG No. 22 7/30 tinned copper drain wire conforming to ASTM B 33 and B 174.

5. Jackets

The overall jacket of multi-conductor cables shall be of flame-retardant, irradiated, cross-linked, modified polyolefin, Tefzel (ETFE), or Teflon (PTFE) to be fully compatible with the wire insulation and application as approved. The jacket shall be extruded and vulcanized over the cabled conductors, and shall be centered, with a smooth appearance without objectionable roughness or irregularities, consistent with good industry practice. The nominal jacket thickness shall be that shown below, with the minimum wall thickness not less than 80% of the nominal value.

Nominal Jacket Wall Thickness in Inches			
Cable Diameter Under Jacket	**Modified Polyolefin**	**Teflon or Tefzel**	**Neoprene**
0.000-0.250	0.045	0.010	0.072
0.251-0.500	0.045	0.015	0.087
0.501-0.750	0.060	0.021	0.100
0.751-1.000	0.080	0.021	0.100
1.000-1.500	0.080	0.025	0.115
1.501-2.000	0.11		0.135
2.001-2.500	0.13		0.152
2.501-3.000	0.14		0.195

E. Wire Wrap

- Wire wrap connections may be used in selected electronic applications, where approved by the Engineer.

TP08.14 WIRING

A. General

All car wiring shall be in conformance with APTA RP-E-002 *"Recommended Practice for Wiring of Passenger Equipment"* and the AAR Manual of Standards, Section F S-538,

"Wiring Practice and Rolling Stock Standard," except where otherwise specified. Circuit protection shall be in conformance with Chapter 2 of NFPA 70, Article 240.

B. Wire Handling

All wiring shall be performed by qualified, experienced wiring personnel using appropriate tools for stripping insulation, cutting, tinning, soldering, harness making, attaching terminals, and other wire fabrication tasks. All wiring tools and equipment shall be used as recommended by the tool and equipment manufacturer.

Wire shall be protected from damage during all phases of equipment manufacture.

When removing insulation, wire strands shall not be nicked or broken in excess of the limits of FAA Specification Number AC 43.13-1A, Section 449, "Stripping Insulation." Additionally, the following criteria shall apply:

Wire Size	Maximum Number of Nicked Strands*
Wires smaller than AWG No.10	None
AWG No.10 through AGW 1/0	7.4%
Above AWG 1/0 through 1600/24	4.4%
Above AWG 1600/24	Graduated Scale

*Definitions:

- A cutoff strand shall count as two nicked strands
- A nick is defined as 25% or more of the strand area damaged or cut more than 33% of its diameter.
- Longitudinal scratches in a copper strand are not considered cause for rejection.

C. Wiring Layout and Installation

1. Wire Harness

Wiring shall be pre-fabricated into standard harnesses, wrapped or tied with spiral wrap or tie wraps. Harnesses shall be installed with identical arrangement and location in each car having similar equipment. Separate harnesses shall be provided for major circuit groups or types, or as required for specified circuit separation. All circuits and branches shall be separated for troubleshooting and searching for undesired grounds. All circuits subject to periodic high potential tests shall be so arranged that they can be conveniently set up for the tests.

The layout of the wiring shall be designed in advance of its installation and in cooperation with those furnishing the related equipment.

Harnessed wires shall not be installed in conduit. Wires from different conduits or other openings shall not be harnessed together with wires running within the box or entering the box through another entrance point.

2. Circuit Separation

Circuits shall be physically separated to reduce the possibility of unsafe conditions, interference, or equipment damage.

The following major circuit groups shall not be harnessed or bundled together, shall not run in the same conduit, and shall be physically separated and secured in enclosures, wire ducts, junction boxes, or other wire routing devices:

- High voltage circuits
- AC circuits
- Communication circuits
- Battery voltage level circuits
- Semiconductor gating voltage level circuits
- Conductors carrying in excess of 100 amps

Wires in circuits with potentials differing by 50 V or more shall be separated by a physical barrier. Where a raceway, duct, junction box, or enclosure is divided into two or more distinct areas by metallic partitions, each area may be considered separately in this application.

All wiring within an enclosure shall be insulated for the highest voltage in the enclosure. All wiring connected to apparatus shall be insulated for the highest voltage connected.

Wiring connected to transient-generating apparatus, such as unsuppressed contactor coils, shall not be run adjacent to wiring carrying signals to, from, or between semiconductor circuits, logic circuits, vital no-motion circuits, or communication circuits.

3. Wire and Cable Runs

Wire runs shall be continuous and unbroken between connection points, shall be supported at no greater than 24-inches spacing, and shall be protected at each support point against mechanical crushing and abrasion. A watertight bushing and drip loop shall be provided on all exposed cable entries.

All undercar wiring smaller than AWG No. 6 shall be run in closed wire ducts, conduits, or open wire mesh wireways in an approved manner. Wire and cable shall be secured within ducts or open wireways, including each entrance and exit point, to prevent chafing and movement. Wire ducts and conduits shall be of waterproof construction. Permanently retained watertight strain relief bushings, with insulated throat liners of an approved design, shall be used at locations where wires, cables, or harnesses enter or exit conduit, ducts, apparatus, and equipment enclosures.

Strain relief bushings on equipment enclosures shall include a permanently retained O-ring type seal.

Lead wires to resiliently-mounted electrical apparatus shall be carried in conduit to a point as close to the apparatus as possible. The length of the leads between the end of the conduit and each piece of apparatus shall be as approved. Short runs of cables or harnesses entering or leaving conduit and apparatus shall have an approved guard mounted to the carbody to protect the wires from mechanical damage. Lead wires to solidly-mounted electrical apparatus and equipment enclosures shall run in conduit connected to the apparatus or enclosure.

Any wiring run through the floor shall be run in ducts or conduit. Wiring must not be run through partitions without suitable bushings at such points of passage.

Cables shall be laid in place with sufficient slack at the bends so that cables will clear the inside bend surface of the wireway/wire duct.

All wire and cable shall be free of kinks, insulation damage, insulation abrasions, and nicked strands. Wire installation shall not be subject to accumulations of water, oil, or other foreign matter.

Wires or cables shall not pass through or over the battery compartment and shall not pass over heat-generating equipment even if the wires or cables are in conduit.

Exposed harnesses, short cable runs, and harnesses entering or leaving exposed raceways shall have approved, fire-resistant, flexible dielectric sleeving installed over the raceway edges and grommet-type insulation at penetration holes.

a. Cable Cleating and Support

All cable and wiring, exiting wireways/wire ducts, and that which is not installed in conduit, shall be cleated using split-block cleats of molded neoprene rubber. Cables shall be cleated and bushed when passing through bulkheads and structural members. The cushioning neoprene shall be non-conductive, fire-retardant insulating material. Each cleat shall have a stiffener of at least 10-gauge material on the side away from the mounting bracket which shall act to spread the bolt clamping force over the entire length of the cleat. Bolts shall have lock nuts.

AWG No. 6 or larger insulated wire may be cleated in place without conduit, duct, or open wireway. In the areas over the truck in the wheel wash and not protected by underfloor-mounted equipment, the wire shall be mechanically protected by an approved guard.

Cleats shall be designed to grip each cable individually and firmly, but without causing damage to cable insulation, including cold flow of the insulation. Cleated cables shall be routed and supported such that they cannot, under any combination of forces and car movement, touch each other or any other part of the car.

Wire and cable runs shall be continuous and unbroken between terminations. Wires that run under the car shall be supported at not greater than 18-inch intervals. The wire shall be protected at each support point from mechanical crushing and abrasion.

Wire splices shall not be permitted.

Concealed wires, such as within conduits and wire ducts, shall be such that wires may be replaced or added to without the removal of other than access panels.

Wiring run in loom shall not be carried over potential chafing hazards.

Wires entering any removable box shall be harnessed and secured to facilitate removal of the box.

b. Wire Securement and Termination

Wiring and cabling shall be readily accessible for inspection and maintenance.

All wiring shall be located and secured such that normal equipment motion, maintenance access, heat sources, and the environment do not damage or reduce the life of the wiring.

Junction boxes with terminal boards shall be used for wire terminations. Exterior junction boxes shall be weathertight.

Wire and cable dress shall allow for sufficient slack at equipment terminals to provide for movement induced by shock and vibration, equipment shifting, alignment, cover removal, and component replacement. Sufficient lengths shall be provided at points of termination for additional reterminations without applying tension to the wire and without splicing as follows:

- AWG No. 10 and smaller – Three reterminations
- AWG No. 8 and larger – Two reterminations

A drip loop shall be provided on all exposed wires and cables to prevent fluid runoff into connected equipment.

Wire-tying devices shall be of such material and construction that they will adequately retain the wires for the life of the wiring and shall be resistant to ozone and ultraviolet light. Wire and cable ties shall be trimmed and located to eliminate any hazard to personnel from sharp edges. Wire-tying devices shall be mechanically fastened to a permanent structure.

All wire bundles and cables within an enclosure shall be supported by the use of tape rails, shall be spaced away from the equipment box structure, metal edges, bolt heads, and other interference points, and shall have electrical clearance from the covers, regardless of the insulation properties of covers.

Truck wiring shall be designed to ensure sufficient slack and shall be provided with clamp supports and abrasion protection. T-splices shall not be permitted.

All jumpers, jumper heads, and jumper receptacles shall be sealed in an approved manner to prevent the entry of water at any operational speed of the car.

Wire and cables that are subject to high currents in fault conditions or normal operation shall be secured against secondary damage from high magnetic forces.

3. Circuit Shielding

The wire shields shall be connected through all applicable connectors and junction boxes. Circuits shall be categorized. Shields in one circuit category shall not be interconnected with shields of another category. Shields used to protect against interference shall not carry signal currents.

Shields on low-level signal wires shall not be interconnected with shields on high-level signal wires in the same category. Each group of shields (other than at the electric jumper receptacles and couplers) shall be carried through on a connector pin or pins, or on terminal strips which shall be in the immediate proximity of the categorized group of circuits.

Coaxial cables used as constant impedance transmission lines shall be terminated as required by the circuit termination design and shall not be considered to be shielded conductors. Triaxial cables may be used as coaxial impedance transmission lines with the outer conductor employed as an RF shield.

The following three guidelines shall be applicable in so far as possible, but are not requirements:

- Shields used to suppress electromagnetic interference (EMI) at all frequencies shall be terminated only at the low potential side of the interference circuit, at the termination which exhibits maximum susceptibility.

- Shields used to protect against the effect of, or to exclude, EMI at frequencies below 150 kHz, shall be terminated either to the low potential side or at the balance point of the protected circuit at the termination which exhibits maximum susceptibility.

- Cables requiring both audio frequency (AF) and radio frequency (RF) shields shall be electrically isolated from each other. The resistance between these circuits shall be at least 500 mega-ohms when 500 V DC is applied. Double shielding shall be required on circuits that are both AF-susceptible and RF-susceptible.

D. Marking and Designation

Wire numbers shall be assigned to all electrical conductors, whether individual wires or

cables, within the entire car. The Contractor shall emulate the numbering system, employed on the existing vehicle.

All wires and cable shall be marked within 305 mm (12 in) of the end of the wire. The methodology and wire marking system employed shall be approved by the Engineer.

Wires shall be identified according to circuit function, wire number, wire segment, and gauge.

Each circuit shall be individually designated from point to point. Common designations for return circuits will not be permitted.

No disassembly of the wire harness or the connection shall be required to read the wire marking. Wires shall be marked with an alpha-numeric circuit designation.

There shall be no duplication of wire codes in unrelated circuits throughout the car. Where there is more than one identical assembly per car, each assembly shall be wired identically to the other(s) and wire marking shall be identical at each assembly.

Wire markers shall meet the adherence and solvent resistance requirements specified by MIL-M-81531, latest revision, and shall withstand all combinations of ambient and equipment temperatures. Hand printing is prohibited.

For cable identification, the Contractor shall use a basic identification system in conformance with ANSI/IEEE 200 and shall submit the system selected for review and approval by the Engineer.

E. Pulling Compound

Pulling compound shall be non-conductive, non-hygroscopic, non-odorous, and shall not support bacterial activity nor attract vermin.

F. Solder

Solder shall be in accordance with ASTM B 32, Grade Sn60. A non-corrosive flux shall be applied immediately before soldering.

G. Tape

Electrical tape shall be in accordance with AAR Standard S-540, or equivalent approved for railway practice. Electrical tape shall meet or exceed the voltage rating of wire where the tape is applied.

TP08.15 WIRE AND CABLE CONNECTIONS

A. General

All equipment enclosures and junction boxes, except primary power circuits, shall be fitted with terminal boards or connectors. Primary power circuits shall be fitted with compression terminals and knuckle joint connectors as described herein. Unused connector pin positions shall be sealed with either connector contacts or plastic sealing plugs designed for that purpose.

IPC/WHMA-A-620 Requirements and Acceptance for Cable and Wire Harness Assemblies shall be integrated into the wiring production plan.

Terminal boards with M4 or No. 6 or smaller screws and quick-disconnect terminals shall be permitted only with prior approval by the Engineer.

B. Terminal Boards and Terminal Points

Molded case, modular terminal blocks which utilize a spring clamp to hold the wire may be used for low voltage circuits. Each terminal block shall be properly identified with a permanent marking and each assembly shall be secured to the mounting (DIN) rail by end clamps which incorporate metallic hardware. All wires AWG No. 12 and smaller shall receive a ferrule. All molded case, modular terminal blocks are subject to review and approval by the Engineer.

All other electrical terminal points and terminal boards shall be one of the following types:

- Stud type in accordance with MIL-T-55164A
- Binding head screw type in accordance with MIL-T-55164A, only where approved.

Stud-type terminal points shall have brass studs and connections, each of which shall be locked using a single brass nut with brass flat washer and a plated spring-type lock washer. Studs, nuts, and washers may also be made of corrosion-resistant, plated steel, where approved. All terminal boards shall be in accordance with Military Specification MIL-T-55164A.

Threaded studs shall have a minimum of 2 1/2 threads exposed beyond the final nuts. Adequate space shall be provided to permit connecting wire terminals with standard tools. All terminals shall be properly torqued to assure sound connections.

Jumpers between terminal board points shall be brass or plated steel.

A maximum of two terminals shall be connected to any one binding screw. A maximum of four terminals shall be connected to any one threaded stud, provided that there is no interference among terminal barrels. On terminal boards, the wiring shall be arranged so that no more than two terminals are connected to a stud from each side.

C. Wire Terminations

Terminals and connections used throughout the car shall be mechanical, solderless, crimp type as manufactured by AMP Incorporated or other approved manufacturer with a comprehensive line of terminals, connector pins, and application tools available. All terminals for the same wire size shall be crimped with the same model tool and attached to the wiring with proper crimping tools and dies as recommended by the manufacturer.

The terminals used on AWG N0. 10 and smaller wires shall securely grip and hold the insulation of the conductor, unless otherwise approved. Terminals shall be ring lugs in accordance with Military Standard MS-25036; spade and hook-type terminals shall not be used.

Conductors subject to motion relative to the terminal shall be protected to prevent breakage of the conductor at or near the terminal. Sufficient slack shall be provided in all wires and cables to prevent breaking or pull out of bushings and terminals. Only one wire shall be crimped in any one terminal.

Wherever several wires are connected to terminals of a terminal strip on a device which is removable from the car for maintenance, the wires shall be terminated, with double-ring terminations which shall be screwed to an insulating fanning strip which shall serve to keep the terminations in the correct relative locations while disconnected from the device, unless otherwise approved by the Engineer.

D. Power Cable Terminations

Power cables shall be terminated with an approved compression terminal. Sufficient cable slack shall be provided to preclude breaking or pull-out from bushings or terminals and to allow two reterminations. Compression terminals shall be applied using tools and procedures recommended by the terminal manufacturer for that purpose. Swaging tools shall be of a type that ensures complete swaging in every case.

E. Cable Connectors

All cable connector applications shall be subject to approval.

Unused connector pin positions shall be sealed with either connector contacts or plastic sealing plugs designed for that purpose.

All cable connectors shall conform to MIL-C-5015 or an equivalent standard as approved. They shall employ removable crimp contacts of the correct size for the wire being terminated.

Adjacent connectors shall use either different inserts or different insert orientations to prevent erroneous connections. The receptacle portion of all cable connectors shall be rigidly mounted.

All cable connectors used in exterior locations shall be of the environmental watertight variety. Cable connectors shall be equipped with sealing gaskets on the front mating surface and on the back where the cable enters. The cable jacket shall be held by a clamp within the connector body.

Plastic-bodied connectors shall not be used in exterior locations.

Quarter-turn, bayonet-lock connectors shall conform to all provisions in MIL-C-5015, or other approved standard, except for the screw coupling requirement.

Connectors in high vibration or high motion areas shall have the wire connections soldered and potted and shall have a watertight jacket molded over the cable and connector to form a unitized assembly.

F. Quick-Disconnect Terminals

Quick-disconnect terminals shall be utilized to facilitate maintenance and inspection. They shall provide positive terminal engagement and be shock- and vibration-proof. All terminals shall be provided with insulation equal to that of the wire. No "push-to-fit" (FASTON) type terminals shall not be permitted unless specifically approved by the Engineer.

G. Grounding

1. Connections

Grounding connections to carbody and equipment shall be made through silver-soldered or brazed copper pads of an area adequate for the anticipated maximum current that may be carried under any circumstances. Transition (base) plates, if used, shall be of the same alloy group as the respective carbody part or apparatus. The base plate shall be welded to the carbody or apparatus.

All ground pads shall be visible and accessible for inspection and troubleshooting. The ground connections shall be attached by a bolt, washer, and nut designed for the purpose. Anti-corrosive grease shall be applied over the connection.

All equipment enclosures and shock-mounted equipment shall be grounded with flexible, grounding leads bolted between a car body grounding pad and the equipment's grounding pad. Braided, strap-type leads shall be used where there is relative motion between the two items being connected. The ground strap termination method shall apply uniform pressure to the conductive surface and the current density shall not exceed the bonding requirements.

Ground cables and shunts shall not be less than No. 10 AWG.

2. Bonding

All grounding and bonding jumpers and straps shall be sized to carry fault current and lightning discharge current for which the voltage drop shall not exceed 25 V. The bonding method employed shall not produce a DC resistance in excess of 0.0025 ohms, or more than 0.025 ohms at 150 kHz for any applied AC voltage. Grounding and bonding jumpers and brazed shunt straps shall be "extra-flexible."

H. Wire Splicing

Splicing of conductors shall be permitted only with approval by the Engineer on a case-by-case basis. Splicing of conductors in conduit shall not be permitted.

TP08.16 CONDUIT

A. Types

All conduit and conduit couplings shall be of an ANSI-approved type. All exterior rigid conduit shall be standard weight, galvanized steel with threaded fittings. All conduit ends shall be deburred inside and out to remove sharp edges and all pieces shall be blown out with compressed air and cleaned before installation to remove filings and other foreign material.

Steel conduit shall be mild steel in standard lengths with threaded ends and hot-dipped zinc-coated exterior and interior surfaces. Conduit shall conform to the requirements of ANSI Standard C-80.1. The threads per inch and length of threading shall conform to ANSI Standard B-2.1 for pipe threads.

Steel fittings shall be used to assemble steel conduit. Elbows, nipples, and couplings shall be made of the same grade of steel as that of the conduit. All fittings shall be treated, coated, and threaded according to the requirements for zinc-coated, rigid steel conduit and shall conform to UL 6.

Flexible conduit shall be watertight and interlocking aluminum, or steel strip protected, with an approved rust-resistive coating. Flexible covering on conduit shall not contain polyurethane, nylon, or PVC vinyl. Cross-linked polyolefin may be used.

Liquid-tight flexible nonmetallic conduit, if required for special applications, may be used with the Engineer's approval. Liquid-tight flexible nonmetallic conduit shall not be used where subject to physical damage or in lengths longer than 6 feet.

B. Installation

All conduit bends and offsets used shall be made by the use of special forms or tools and shall have the largest radius possible so that wires can be pulled without the use of tackle or power.

Conduit shall be securely clamped with all runs electrically grounded to make a continuous ground.

All conduits shall be arranged to prevent moisture traps and shall drain toward control boxes, except that all open-ended conduits shall be installed in such a manner as to ensure gravity drainage out the end. Conduit shall be supported to the carbody at least every 24 inches.

TP08.17 CONDUIT FITTINGS AND JUNCTION BOXES

A. General

All conduits and their connections to electrical equipment shall be installed to make a continuous ground. All conduit fittings and junction boxes shall be provided with gaskets. Gaskets for conduit fittings and covers shall prevent the ingress of dust, debris, and water encountered in the operating environment.

B. Boxes

All exterior junction boxes shall be fabricated of minimum 14-gauge steel or aluminum (where permitted). All exterior junction boxes shall be weatherproof and shall be connected in such a way that drainage from equipment groups will not pass through conduit into the junction boxes.

Interiors of all junction boxes shall be primed and then protected with a white, insulating coating.

C. Conduit Interface

The open ends of conduit shall be provided with strain relief-type fittings with extended rubber bushings, bell-mouth fittings, or insulated throat box connections as approved by the Engineer. All conduit entries into removable equipment boxes shall be secured by means of a bolt-on watertight access panel.

D. Covers

All junction box covers shall be retained captive screws as approved on a location-by-location basis. All fasteners used in junction boxes shall be stainless steel. All covers shall be designed to accept or mate with an approved seal/gasket.

TP08.18 WIREWAYS

All wireways shall be of rigid, stainless steel construction. The trays shall be completely de-burred, leaving absolutely no sharp edges, before installation on the vehicles. Grommet clamps shall be provided at all locations where cables or wires enter or leave the wireways. Metal wireways, elbows, couplings, and similar fittings shall be flush with the metal surface.

The wireways shall be routed such that they avoid:

- Sources of heat;
- Wheel splash; and
- Areas subject to damage by debris or foreign objects.

Wireways shall be located to provide access to the harnesses contained within for maintenance. They shall be provided with approved covers which may be interrupted for entry and exit of wires and cables.

Wireways shall be designed to prohibit the collection of dirt and debris, and shall be perforated, without compromising their requisite strength, to permit ventilation and drainage. They shall preclude water entrapment.

Metal raceways and the elbows, couplings, and fittings shall be electrically and mechanically coupled while protecting wires from abrasion, and shall make a continuous ground with the car structure.

Bends in wireways shall be avoided; however, if required, approved protection shall be provided to avoid insulation chafing at the bends.

All wire and cable shall be securely fastened within wireways to eliminate movement and chafing.

TP08.19 WELDING AND BRAZING

A. General

The Contractor shall be responsible for the quality of its welding and brazing as well as that of its suppliers and subcontractors. Cleaning prior to welding shall be in accordance with applicable parts of Section 2, MIL-HDBK-132, *"Protective Finishes."*

B. Structural

All structural welding practices shall be according to requirements of the AWS D1.1, *"Structural Welding Code – Steel;"* AWS D1.2, *"Structural Welding Code – Aluminum;"* AWS D1.3, *"Structural Welding Code – Sheet Steel;"* AWS D1.6, *"Structural Welding Code – Stainless Steel;"* AWS D15.1, *"Railroad Welding Code;"* and the AWS Handbook. Requirements for dynamically loaded structures shall be applied. Cast steel welding shall be according to ASTM A 488/488M, *"Steel Castings, Welding, Qualification of Procedures and Personnel."* Resistance welding shall be in accordance with AMS-W-6858B. AWS D1.1 shall apply to steel of 1/8-inch and greater thickness. AWS D1.3 shall apply to steel less than 1/8-inch thickness.

Structural welding of ferritic and austenitic stainless steel shall be governed by AWS D1.6. ASME Section IX and ASME Section VIII, Part UHA shall apply when appropriate. AISI 201L (UNS 20103) and 301LN (UNS 30153) stainless steels shall be treated as P-Number 8, Group-Number 3, category for reference to ASME requirements. Ferrite number for welds shall be between WRC4 and WRC10, or as proposed by the Contractor and approved by the Engineer. Weld heat-affected zones (HAZ) and weld metal shall be limited to maximum allowable stress values in ASME Section VIII, Table UHA-23, for UNS S20100 stainless steel and Table UW-12 rating of welds. Fatigue allowable stresses shall not exceed the lesser of fatigue limits in AWS D1.1, Section 2.20.6, or 50% of the joint strength level calculated from ASME maximum allowable stress values. Higher values shall only be used if qualified by Contractor tests.

All Welding Procedure Specifications (WPS) shall be fully qualified by test by the Contractor. The use of AWS-B2.1 shall not be permitted and shall not be included or referenced in Welding Procedure Specifications (WPS) and Procedure Qualification

Records (PQR). The use of any WPS purchased from AWS shall not be permitted. All WPS shall be fully qualified by the Contractor PQR-welding tests and subject to approval by the Engineer and a Certified Welding Inspector.

C. Welder Qualification

Welders shall make only those welds for which they have been qualified according to the requirements of the AWS, ASME Section IX, ASTM A 488/488M, or other approved qualifying procedures. (AWS B2.1 shall not be used, as noted above.) Records of welder qualification tests shall be made available for review.

D. Inspection

The Contractor shall visually inspect all structural welds in accordance with AWS D1.1 requirements.

Nondestructive surface inspection (dye penetrant or magnetic particle methods, as appropriate) shall also be used to inspect all first-production welds. The Contractor shall specify a sample nondestructive inspection rate for all subsequent welds. A record of all NDT inspections shall be included in the Car History Book.

E. Post-Weld Cleaning Requirements

All welds exposed to passengers or on sliding contact surfaces of truck frames and bolsters shall be completely cleaned of spatter.

F. Special Welding

Procedures and qualification records for structural welding of stainless steel to LAHT, or other combinations of metals or conditions not covered by AWS specifications or codes, shall be submitted for approval. As part of the qualification of all dissimilar metal welds, sample welds shall be sectioned and examined metallographically to determine HAZ hardness. The HAZ hardness shall not exceed 400 HV (Vickers Hardness).

Austenitic stainless steel electrodes or wire shall be used to join carbon or LAHT steels to stainless steels. Galvanized steel shall not be welded to stainless steel.

G. Resistance Welding

Resistance welding of stainless or carbon steels shall be according to AMS-W-6858, Class B for structural applications and Class C for non-structural applications. All resistance welding procedures shall be qualified per AMS-W-6858B.

Design strengths higher than standard certification and production strength requirements shall be qualified according to AMS-W-6858, Figure 11b, for one thickness. This shall require a test lot size of 180 spot welds.

Surface indentation shall not exceed 20% of material thickness (t) or 0.01 inch, whichever is greater. For exterior resistance-welded areas exposed to passenger view, indentation shall not exceed 10% of t or 0.005 inch, whichever is greater. Surface burn and

discoloration shall be removed by chemical cleaning, or an approved equal method, and sanding or polishing to match the surrounding surface.

H. Resistance Spot Weld and Intermittent Weld Spacing

Spacing of structural resistance and spot welds shall be according to approved structural drawings.

For non-structural applications, weld spacing shall be designed and qualified in accordance with the appropriate welding code requirements.

I. Toughness of Welded Assemblies

The Contractor shall prove all welded steel structures are above the ductile-brittle transition temperature for the specified environmental exposure. Specifically, the weld heat-affected zone (HAZ) and base metal shall resist service impact loads at the lowest specified operating temperature without brittle failure.

The Engineer shall have the right to require impact tests to verify the specified toughness. Verification of HAZ toughness shall be done on a test sample welded according to PQR parameters. Base metal toughness shall be certified on a heat basis by the steel manufacturer or steel supplier; if these data are not available, the Contractor shall perform tests on each heat of as-received base metal.

J. Torch Brazing

All brazing, defined as heating above 840 degrees Fahrenheit, shall follow the recommendations of the latest AWS Welding Handbook, Volume 2 issue. Procedures and personnel who perform brazing work shall be qualified in accordance with AWS B2.2, *Standard for Brazing Procedure and Performance Qualification.*

K. Torch Soldering

All structural (not electrical) soldering, defined as heating below 840 degrees Fahrenheit, shall follow the recommendations of the latest AWS Welding Handbook, Volume 2 issue. Procedures and personnel who perform torch soldering shall be qualified through the preparation and testing of samples of production torch soldering. Test samples shall be prepared and submitted for approval before production torch soldering.

TP08.20 PAINTS AND COATINGS

A. General

All painting on the carbody or any component shall be performed in accordance with the paint manufacturer's recommendations.

B. Materials and Preparation

Preparation of the substrate surface and application of painting materials by roller, brush, or spray shall be in accordance with the paint manufacturer's recommendations. Only primers recommended and approved by the paint manufacturer shall be used. Painting

shall be performed by experienced labor, using proper equipment under competent supervision following documented and approved procedures.

Painting materials for all surfaces shall provide a high quality finish resistant to corrosion, chipping, fading, and shall retain the gloss level. All components of the paint system shall be provided by the same manufacturer. All paint and filler materials which are to be superimposed to form a finish system shall be mutually compatible and shall be warranted for use as a system by the manufacturer of the components.

C. Exterior Painting

All exterior surfaces that are to be painted shall be prepared as specified, and the paint shall be applied according to the paint manufacturer's recommendations. The paint shall be free from runs, sags, or other application defects.

Before painting any car surface that is exposed to view, all dents, gashes, nicks, roughness, or other surface imperfections or depressions shall be removed, in so far as possible, by straightening and shall then be properly prepared to receive a filler material. These surfaces shall be properly cleaned and wash primed following straightening. Any remaining dents or other surface imperfections shall then be filled with an approved filler and sanded smooth. The maximum allowable filler thickness shall be as recommended by the filler manufacturer for the environment and service to which it is to be exposed.

D. Apparatus and Underfloor Equipment

All underfloor- and overhead-mounted apparatus shall be primed and painted in accordance with the following requirements unless otherwise indicated. All other apparatus shall be painted in an approved color.

The exterior surfaces of undercar equipment enclosures and apparatus, other than propulsion control equipment, made from carbon steel shall be prepared, primed, and painted.

The interior and exterior surface of all electrical equipment enclosures shall be coated with an approved insulating, thermosetting, resin-based, powder coating or polyurethane paint system.

Parts of undercar equipment enclosures made from plastic or fiberglass shall be painted in accordance with the above requirements for metal portions, except that the paint system shall be compatible with the plastic used and an insulating coating need not be applied.

E. Painting Restrictions

Any equipment or parts of equipment which can be damaged or suffer impaired operation from painting shall not be painted and shall be corrosion resistant.

The following items shall not be painted:

- Copper tubing, piping, and fittings;

- Wearing surfaces;
- Couplers, including yoke and draft gear;
- Wire and cable;
- Power resistors;
- Heat transfer surfaces;
- Electrical insulators;
- Elastomeric parts;
- Grounding pads; and
- Conduit and fittings.

The following truck-related items shall not be painted:

- Wheels;
- Axles;
- Elastomeric parts;
- Grease fittings;
- Linkages;
- Threaded adjustment parts;
- Electrical equipment; and
- Wearing Surfaces.

F. Interior Painting

Interior surfaces requiring painting shall be coated with an approved painted finish in accordance with the recommendations of the paint manufacturer.

The Contractor and its paint manufacturer shall provide a touch-up procedure and assure that a continued supply of touch-up paint in the proper colors suitable for spot application will continue to be available in the United States.

G. Acoustic Insulation

Acoustic insulating materials shall be applied to properly cleaned underframe, sides, ends, roof and floor sheets, in accordance with the supplier's recommendations. The materials shall be resistant to dilute acids, alcohols, grease, gasolines, aliphatic oils, and vermin. The material shall be unaffected by sunlight and ozone and shall not become brittle with age. It shall be Daubert Chemical Company's V-Damp 3680 sound deadening compound, 3M Corporation's 2552 Damping Foil, or approved equal.

H. Thermal Insulation

Thermal insulation materials shall be transportation grade of the rigid, non-rigid, or spray-on type. Insulation shall be installed with a vapor barrier to preclude moisture accumulation.

The type of thermal insulation to be used shall not be susceptible to mold or rot and shall not absorb water. Metals, which are attached to the insulation, shall be corrosion resistant, and not settle under vehicle vibration. The vehicle thermal insulation shall not have an odor or be capable of absorbing odors, and shall not sustain vermin. Urethane foam insulation is expressly prohibited.

Thermal insulation material shall have the same thermal conductivity as the originally used material.

TP08.21 FLAMMABILITY, SMOKE EMISSION, AND TOXICITY REQUIREMENTS

A. General

All combustible materials used in the construction of the cars shall satisfy the flammability, toxicity and smoke emissions requirements of this Section and 49 CFR 238.103 and NFPA 130. In case of conflict, the more restrictive requirement shall prevail. The Contractor shall comply with all provisions of APTA RP-PS-005-00, *"Fire Safety Analysis of Existing Passenger Rail Equipment."*

B. Toxicity

Materials and products identified by state agencies, Federal agencies, and the American Conference of Governmental Industrial Hygienists (ACGIH) as containing toxic properties or to emit toxic products of combustion in excess of the limits defined in the Technical Provisions shall not be used. Materials and products generally recognized to have highly toxic products of combustion shall not be used.

All materials used in the car construction, except for materials used in small parts such as knobs, rollers, fasteners, clips, grommets, and small electrical parts that would not contribute significantly to fire propagation or to smoke or toxic gas generation and are distributed throughout the car, shall be tested for toxicity using Boeing Specification Support Standard BSS-7239. Alternative test protocols may be proposed for the Engineer's consideration providing that the results are reported as noted below. Materials

shall meet the following maximum toxic gas release limits (ppm) as determined per BSS-7239:

Carbon Monoxide (CO)	3,500 ppm
Hydrogen Fluoride (HF)	200 ppm
Nitrogen Dioxide (NO_2)	100 ppm
Hydrogen Chloride (HCL)	500 ppm
Hydrogen Cyanide (HCN)	150 ppm
Sulfur Dioxide (SO_2)	100 ppm

The tests shall be conducted in the flaming mode after 240 seconds using the NBS Smoke Density Chamber for sample combustion. The gas sampling may be conducted during the smoke density test.

C. D. Electrical Fire Safety

Electrical equipment, wiring and apparatus shall conform to NFPA 130 except where more restrictive requirements are imposed by the Technical Provisions.

TP08.22 ELECTRICAL AND ELECTRONIC DESIGNS

A. General

Except as otherwise noted herein, electronic equipment shall conform to IEC 60571, *Electronic Equipment Used on Rail Vehicles*, Class TX, unless otherwise approved by the Engineer.

B. Ability to Repair

Where practical, all electrical assemblies, including such items as PC boards, shall be designed for repair by the maintenance staff in their electronics laboratory.

Assemblies that must be potted or sealed or can not be repaired by design shall have a minimum 10 year warranty. Such non-repairable components shall be identified and shall be designed to allow unit replacement.

All USB connections and all other removable storage devices shall have a sacrificial pass through connector that can be easily replaced without requiring special tools or unsoldering.

C. Hardware

All hardware associated with electronic and electrical control systems shall be protected against moisture, oxidation, and common airborne contaminants.

D. Enclosures/Racks

All circuit boards that are rack-mounted shall plug into racks containing the mating half of the circuit board connector. The rack, circuit board, and circuit board hardware shall be designed as an integrated system. All circuit boards and connectors in a rack shall be keyed to ensure the correct board is installed in the proper location.

The rack and enclosure shall provide environmental and EMI shielding to meet the requirements of the Technical Provisions.

Printed circuit boards shall be positively retained. The enclosure or rack cover shall not be used to retain the circuit boards, unless specifically designed to do so.

The rack and the edge of each board, or the card ejector, shall be labeled with corresponding numbers to identify board location within the enclosure.

The enclosure/rack shall not be connected to the power supply return or signal common.

Where it is necessary to use printed circuit boards that are not plug-in and not mounted in an enclosure, the following additional requirements shall apply:

- The PC board shall be protected from mechanical damage and hostile environments such as arc discharge and contact with high voltage.
- If the PC board is part of a high voltage circuit, it shall be design with regard to strike distance and creepage in the rail vehicle environment. APTA RP-E-004-98 shall apply where applicable.
- Any test points required in routine testing or fault isolation to the user replaceable level, shall be easily accessible without disassembly or tools.

If replacement of the PC board is required, no special tools or soldering shall be required. Each PC board use and application of this type shall be subject to Engineer approval.

E. Optical Fibers

Any application of optical fibers shall be approved by the Engineer prior to implementation. The connections between optical fibers and car-replaceable units shall be via approved "quick-disconnects."

TP08.23 ELECTRICAL DEVICES AND HARDWARE

A. General

All electrical devices shall be rail industry proven.

B. Contactors and Relays

All contactors and relays shall meet the following qualifications.

Devices shall be tested for proper functioning in orientations up to 30 degrees from the orientation in which they are mounted in the vehicle in each of the three possible rotations: pitch, yaw, and roll.

Contactors and relays shall comply with the requirements of MIL-R-6106 (for ratings of 10 amperes or greater) and MIL-R-5757 (for ratings of less than 10 amperes.

All devices shall be constructed and utilized in a fail-safe manner such that passengers, crew, and equipment are not placed in jeopardy.

All devices shall be installed so that they are fully accessible for inspection, trouble-shooting, repair-in-place, or removal and replacement. Contactors and relays shall incorporate means of visually determining whether they are picked up or dropped out.

There shall be a maximum of two wire terminations on any one contact of any device.

The coils of all devices shall be suppressed to protect the low-voltage network from transients.

Contact tip ratings shall be stated for the worst condition of reduced surface contact which may result from tip misalignment and wear during normal operation.

Contactor installation shall be such that the arc spray is directed by an arc chute away from ground and any other electrical devices proximate to the contactor.

All contactors shall be constructed so that the main contact tips make and break with a wiping motion that prevents deposits and pitting.

All DC contactors shall have series-fed blowout coils. The Contractor shall demonstrate the ability of each contactor type to reliably interrupt current over the full design operating range.

The identification strip shall be mounted adjacent to the mounting of said device.

Bifurcated contacts shall be used in low voltage applications, whenever necessary, due to dry contacts or low current switching requirements.

All time delay relays shall be of the R-C delay or solid state type.

Where plug-in relays shall be positively retained by means of a retaining clip or bar. When the relay is removed, the retainer shall itself be retained so that it cannot come in contact with devices which may have exposed energized electrical circuits, and it shall not interfere with the operation of any other device when in this position.

Adequate gap and creepage distances shall be maintained from high voltage contactor tips and low voltage coil and auxiliary contacts, to prevent entry of high voltage arcs or transients into low voltage circuits.

C. Switches

Under no circumstances shall poles of switches be placed in parallel in order to carry currents in excess of the contact pole rating given by the manufacturer.

Switches shall be provided with a "keying" feature so that after installation, the body of the switch is constrained from mechanical rotation.

All control switches subject to water splash (switches mounted near windows or doors, or mounted on the Operator's console) shall be environmentally sealed. Toggle and push button switches shall be per MIL-S-3950, MIL-S-8805, MIL-S-83731, or equal.

There shall be a maximum of two wires connected to each terminal of the device.

Switches shall be individually replaceable by disconnecting only the mounting fasteners and electrical connections of the switch to be replaced.

All switches and pushbuttons shall comply with the following requirements:

- Contact resistance shall be less than 0.050 ohm at 3 V DC and 10 milliamps.
- Open circuit resistance shall be 50 mega-ohms minimum.
- Resistance to case shall be 1000 mega-ohms minimum at 500 V DC.

Contact shall be rated for inductive loads. The contacts shall normally operate at not more than 20 percent of the manufacturer's inductive rating for 25,000 cycles of operation at 25 °C. The electrical contact material shall be plated with silver or silver with a gold flash or gold plate, and be normally a break-before-make type.

D. Circuit Breakers

1. General

All circuit breakers of the same rating shall be of the same manufacture and model throughout the vehicle. Circuit breakers shall be Din Rail mounted when ever possible.

The "ON," "OFF," and "TRIPPED" positions of all circuit breakers shall be permanently marked on the handle or the case of the circuit breaker. The circuit breaker, when tripped, shall assume a distinct position to permit determination that it has been tripped by either its overcurrent or shunt trip elements. All circuit breakers shall be mounted in the vertical direction with the "ON" position up.

Circuit breakers shall be individually replaceable by disconnecting only the mounting fasteners and electrical connections of the breaker to be replaced.

Electrical connections to circuit breakers shall either be threaded to accept machine screws or use a threaded stud.

All circuit breakers shall be sized by current rating and trip time to protect both the associated equipment and the minimum size wire used for power distribution within the protected circuit without causing nuisance trips.

Each circuit breaker pole shall be equipped with a means of arc extinguishment to prevent flashover.

The continuous current rating of thermal-magnetic trip circuit breakers shall be selected in accordance with ANSI C37.16 for the load and type of service specified.

All thermal-magnetic trip circuit breakers shall conform to the requirements of ANSI C37.13 and ANSI C37.14.

Circuit breaker current rating shall be clearly and permanently marked.

2. High Voltage Circuit Breakers

All distribution-type, high voltage circuit breakers shall be Westinghouse Series C, FDB frame, Heinemann type GH, or approved equal.

The trip elements shall be thermal-magnetic, or magnetic, connected in series.

The circuit breaker handle shall protrude from the circuit breaker panel cover sufficiently to be manipulated in all positions.

3. Low-voltage Circuit Breakers

Low voltage circuit breakers shall be either one-pole or two-pole devices, depending on the intended function. Trip elements shall be thermal-magnetic, or magnetic, as appropriate for the application.

All low voltage circuit breakers shall be:

- General Use – Westinghouse Series C, Quicklag C frame, Heinemann Series AM, or approved equal, with front connection, and approved labeling.
- Fast Operation – Airpax type IMLK, dust sealed, magnetic breaker, or Airpax type UP, hermetically sealed, magnetic breaker, or approved equal.

E. Fuses

Fuses shall be used only where specifically called for in the Technical Provisions and only with specific approval. Fuses may be considered in applications as follows:

- To protect solid state equipment from catastrophic damage.
- Where current or voltage levels prohibit circuit breakers.

Fuses shall be permanently identified in a location adjacent to the fuse. The rating of each fuse shall be permanently and clearly marked directly on each fuse.

Fuses shall be readily accessible.

Fuse holders shall contain fuse retention devices at both ends.

Air gap and creepage distances shall be subject to approval by the Engineer. APTA RP-E-004-98 shall apply where applicable.

Voltage ratings for fuses in high voltage circuits shall be submitted for review and approval by the Engineer.

High voltage fuses shall be mounted in totally enclosed, dead front fuse holders, with no exposed high voltage connections. The fuse shall be extracted from the circuit when the fuse holder is opened and the exposed fuse shall be safely isolated.

F. Bus Bars

Bus bars shall be fabricated from OFE (Oxygen Free Electronic CDA C10100) or ETP (Electrolytic Tough Pitch CDA C11000) copper. Bus bar conductivity shall be 100% IACS. All bus bar joints shall be silver or tin plated.

Current densities, other than at joints, shall not exceed 1,000 amperes per square inch, and in any case shall not exceed a value which would cause a bus bar temperature rise greater than 86 degrees Fahrenheit (30 degrees Celsius). Current densities in brazed joints shall not exceed 150 amperes per square inch.

Bus bars shall be properly brazed together at joints unless bolted connections are found to be absolutely necessary for maintenance purposes and have been approved. The overlap at bus bar joints shall be no less than 10 times the thickness of the bus material. Bus bar connection bolts shall be torqued to obtain a uniform bus bar connection pressure of 200 psi. Bolting hardware shall be plated steel with Belleville washers to maintain connection pressure. Current densities in bolted joints shall not exceed 300 amperes per square inch for a minimum bolt size of 5/16 inch. The bus temperature rise including joints shall not be greater than 86 degrees Fahrenheit (30 degrees Celsius) above 104 degrees Fahrenheit (40 degrees Celsius) ambient.

Except for connection areas, bus bars shall be safety-insulated, using a high-dielectric powder coating, heat shrink tubing or other approved means. Bus bars that are behind insulating panels are exempt from this requirement.

G. Capacitors and Resistors

Capacitors shall be derated 20% for voltage based on the nominal supply voltage and maximum case temperature. If filter capacitors are exposed to low ripple voltages, lesser values of derating may be accepted if it can be shown that reduced operating temperatures can be achieved due to reduced dissipation. The sum of the DC and AC

ripple voltages shall always be less than the capacitor's voltage rating at a maximum case temperature of 185 degrees Fahrenheit (85 C).

Except for braking power resistors, all resistors shall be derated 50% for power dissipation. Applications for approval of less derating may be submitted on a case-by-case basis.

H. Transformers and Inductors

Transformers and inductors shall be derated 10% for current. Transformers shall:

- Have vacuum-impregnated windings.
- Be rated to withstand at least twice the maximum peak-to-peak voltage that they shall be subjected to in operation.
- Not emit audible noise in excess of 60 dB referenced to 20 micropascals at a distance of 2 feet while operating at rated voltage and load.
- Be designed to minimize radiated and induced EMI.

Power inductors shall have vacuum-impregnated windings and shall be rated to withstand at least twice the maximum peak to peak voltage expected in normal operation.

I. Motor Starters

Motor starters, if used, shall be rated for continuous duty and, shall be equipped with magnetic holding coils.

Starters shall be equipped with sufficient auxiliary contacts to comply with requirements for annunciator circuits, as indicated.

Thermal overload protection shall be provided.

Three-phase starters shall be three-pole.

TP08.24 CONTRACT DELIVERABLE REQUIREMENTS LIST

CDRL #	Title	Reference Paragraph

End of Section