AMTRAK
Mechanical Department
Bureau of Rolling Stock Engineering

GENERAL SPECIFICATION

for

Vehicle Materials and Workmanship

SPECIFICATION No. 328

Revision 1

Issue Date: March 24, 2008

Approved	Date	
	31 March 08	Chief Mechanical Officer
	3/26/08	Senior Director - Rolling Stock Engineering
	3/24/08	Director-Rolling Stock Engineering
	3/24/08	Originator

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Specification Change Sheet

Revision	Date	Section(s)	Description	Approver
Initial	2/22/1990			
1	3/24/2008	All	Document entirely revised	M.L. Burshtin

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General Specification for Vehicle Materials and Workmanship

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General Specification for Vehicle Materials and Workmanship

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1.0 General

1.1 Requirements

Amtrak experience indicates that rail vehicle materials and workmanship must be to a high standard to achieve satisfactory vehicle service under the environmental and operating conditions which prevail. Specific standards with respect to materials and workmanship are necessary. This Specification defines the minimum performance requirements for materials to be used in the manufacturing of components for Amtrak rail vehicles and establishes minimum guidelines for workmanship. It identifies mandatory government requirements and industry specifications controlling the quality of specific materials and components and the construction methods. All Specifications and applicable standards cited in this Specification shall be the latest issue of the document. The vendor shall ensure that all equipment, materials, manufacturing, assembly, workmanship and installation processes and practices are in full conformance with the intent and the requirements of this Specification as well as with proven and recognized industry practices and recommendations.

The vendor shall use only new parts for all components, unless otherwise specified on any Amtrak-provided drawings or contract documents. It is Amtrak's desire that all materials, to the greatest extent possible, be of commonly available commercial items and hardware.

Whenever in this Specification an article or material is defined by using a trade name or the name and catalog number of a particular manufacturer or vendor, or a limited description, the term “or approved equal” if not written thereafter shall be implied. Any reference to a particular manufacturer’s product, either by trade name or limited description, is only for the purpose of setting a standard of performance, quality, composition, construction or size. The term “or approved equal” means any other manufactured product or article which is equivalent in material, workmanship and service and is as efficient and economical in operation in the opinion of the Amtrak Engineer. Amtrak’s opinion as to whether the proposed alternate is equal to the specified items for Amtrak’s specified use and purposes shall be final and conclusive.

Where material test requirements are specified, previous third-party test results or certifications of compliance of previous applications of the identical material may be considered by the Engineer, if not disallowed by statute, for "proof-of-design" consideration in lieu of contemporary test results. Material tests for quality control (routine tests) must be conducted and documented as specified. Applications of materials shall be to best utilize inherent strengths and to avoid weaknesses.

All workmanship shall be high grade and shall conform to the best manufacturing practices in all respects for United States railroad passenger rolling stock. All equipment shall be the same in all respects, after any modifications are made. The materials, assembly methods and overall design shall result in a minimum level of corrosion during the component's life. Any food

service, sanitation or other public health items supplied under this Specification must comply with the applicable requirements of the Food and Drug Administration (FDA) of the US Department of Health and Human Services, and also the National Sanitation Foundation (NSF). The use of asbestos, polyurethane insulation, or polyvinyl chloride (PVC) except for electrical tape, is prohibited.

1.2 Exceptions

In order to avoid any misunderstandings of the vendor's interpretations, it will be assumed by Amtrak that, unless otherwise specifically identified in writing and approved by the Engineer, the vendor will use all the materials and workmanship standards listed within this Specification, and takes no exceptions. If the vendor wishes to use alternative materials or workmanship standards, the vendor must first provide detailed information for review and approval by the Engineer. Alternative standards will be considered by the Engineer only if sufficient information and detailed comparison is provided to clearly establish equivalent or better requirements. It will otherwise be assumed by Amtrak that the vendor takes no exception to this Specification and is completely compliant with all Specification requirements.

1.3 Specifications and Standards

The design and materials used shall be in accordance with the requirements of the Federal Railroad Administration of the US Department of Transportation, and the American Public Transportation Association's Manual of Standards and Recommended Practices for Rail Passenger Equipment.

1.4 Interchangeability

All similar parts on each item being supplied, and among all other assemblies and their spare parts, shall be designed and manufactured to be identical, both as individual parts and as subassemblies. All assemblies shall mount to the rail vehicles without modification. Model numbers for identical components shall be identical. Replaceable components of any such apparatus shall be fully interchangeable, without adjustments to any part being necessary. Specific approval shall be obtained from the Engineer for each part whose replacement may require an adjustment, and such approval may be granted only where it can be shown to be absolutely necessary.

1.5 Dimensions

All designs, components, dimensions and fasteners used on the components being supplied under this Specification shall be of United States inch-standards, unless the use of metric standards is approved in writing by the Engineer.

The vendor shall provide English dimensioning for its drawings and other communications that are generated. Metric dimensioning may be included, provided that English dimensioning is also present. Fractional measurements shall be expressed as a decimal value, and unless otherwise noted and approved drawings shall be made using third angle projections. First angle projection shall be allowed provided all views are labeled, including the front, top, bottom and side views.

1.6 Legal Requirements

All items being supplied under this Specification must comply with all applicable Federal government requirements for rail vehicles, in particular those identified in 36 CFR Part 1192, Subpart F (ADA Requirements for InterCity Rail Cars), 49 CFR Part 229 (Locomotive Safety Standards) and 49 CFR Part 238 (Passenger Equipment Safety Standards), among others. It is mandatory that all materials used by the vendor for application in passenger cars or the cab interior of passenger service locomotives comply with the flammability and smoke emissions requirements of the latest edition of 49 CFR Parts 238.103 (a)(2) and (b)(2), and the Appendix B requirements (including referenced notes) for the category and function of material so listed. Prior to the first delivery of any material, the vendor must supply the Engineer with a report by a recognized third-party independent testing laboratory certifying that all materials used comply with the 49 CFR Part 238 Appendix B flammability requirements, as it applies.

1.7 Engineer

The Engineer or Amtrak Engineering, as referenced in this Specification or any drawings, is defined as the Senior Director of the Amtrak Bureau of Rolling Stock Engineering within its Mechanical Department, or its written designee. The vendor may be submitting items for the Engineer's approval as required by the Specification. The vendor shall not interpret this process to mean that the Engineer will function as an arm of the vendor's Project Management or Engineering staff. Submissions shall be structured to show how the vendor is responding to the requirements of the Specification, and not on the basis of requiring the Engineer to discover how the vendor is not meeting those requirements. Submissions shall contain sufficient detail to confirm that Specification requirements are being met. Submittals requiring the Engineer's approval prior to implementation shall be reviewed and classified by the Engineer within 30 days from the day the submittal is received based on a rate of submittal that is reflective of the pace of an orderly, properly managed program. Priorities will be given to special cases when possible.

2.0 Flammability and Smoke Requirements

All materials shall meet the requirements of the Federal Railroad Administration of the United States Department of Transportation as contained in 49 CFR Part 238.103 and its Appendix B, and also the latest revision of Amtrak Specification 352. Any floor structure shall have a fire resistance rating of not less than 15 minutes when tested in accordance with ASTM E 119 to 1400 degrees F. Third party laboratory certification must be presented to the Engineer for all applicable materials. The vendor shall also have performed, for review and approval by the Engineer, a fire safety analysis when required in accordance with 49 CFR Part 238.103 (c). Any exceptions shall be decided by the Engineer. Conformance with the flammability and smoke emission standards is solely the responsibility of the vendor.

All vehicle components shall be designed for the prevention of fire, shall provide protection of the public, employees, and emergency response personnel from injury due to fire, smoke, explosion, or panic due to fire, and shall provide protection of system elements from damage by fire or explosion. Equipment that is a potential fire hazard shall be appropriately isolated from the vehicle passenger compartment. The carbody and the floor shall be designed to prevent propagation of an underfloor fire to the vehicle interior. Fire stops shall be provided at all floor and roof penetrations. Enclosures for control and other critical equipment shall be located to provide protection against environmental contamination and mechanical damage. The use of

polyvinyl chloride (PVC) or polyurethane plastic in the vehicle, except as may be identified in this Specification, is prohibited unless approved by the Engineer.

3.0 Environmental Conditions

All components shall comply with the environmental requirements identified in Amtrak Specification 429.

3.1 Requirements

The vendor is required to design and construct all components to be fully suitable for the environmental conditions found in the continental United States, such as temperature conditions, relative humidity, elevation, precipitation (including rain, snow and freezing rain), wind, fogs, ultraviolet radiation, and atmospheric contaminants that may include, but not be limited to, water vapor, deicing salts, ozone, nitrous oxide, hydrogen sulfide, particulates, nitrogen dioxide, sulfur dioxide, carbon monoxide, acidic rainfall, fuel oil, diesel emissions, cleaning solutions, oil vapor, carbon, silica, iron, and copper. The components shall be capable of being operated at the specified performance levels, stored, and maintained without impairment resulting from the natural or induced environmental conditions, such as car washing and use of calcium chloride or other deicing agents, within which Amtrak will operate the vehicles.

The climate factors listed below shall be used as design guidelines and considered operational requirements. Actual localized temperatures and conditions within and under the vehicle will be more severe than the ambient climatic conditions due to conditions such as solar loading, equipment heat emissions, under vehicle heat trapped under high level station platforms and elevated tunnel temperatures, and the vendor shall be responsible for evaluating these factors during its design. The vendor will be required to insure that all components and subassemblies will not be subject to any degradation or damage from exposure to more extreme environmental conditions than those listed below during manufacture, storage and shipment.

3.2 Performance

The components on a vehicle which has been cold-soaked in dead storage conditions (completely non-powered) at minus 30 degrees F shall not be damaged or create any unsafe conditions when power is applied. When power is applied, all equipment shall begin operation and no equipment shall be damaged. Full performance in accordance with all specified requirements shall be obtainable immediately for all components of all subsystems (full performance may be delayed for electronic systems warm-up for initial temperatures below minus 10 degrees F). The air conditioning system condensers and underfloor equipment heat exchangers may be exposed to elevated ambient temperatures of up to 140 degrees F and must operate successfully at those temperatures.

3.3 Characteristics

All components shall function normally in the harsh North American railroad environment withstanding vibration and temperature extremes from minus 40 degrees F to 130 degrees F (with maximum temperature when unpowered of up to 150 degrees F), changes in pressure altitude from 0 to 10,000 feet, relative humidity varying between 5 and 100 percent, rainfall amounts of up to 2 inches per hour, snowfall amounts of up to 3 feet in 24 hours, and freezing

rain accumulation of up to 1 inch thickness. Rain acidity may have a pH as low as 4.0.

4.0 Track and Physical Characteristics

4.1 Track

As information, Amtrak vehicles are operated over rail tracks which are in compliance with FRA Track Standard Classes 1 through 6. The vehicle design considerations for maximum track deviations shall be based upon the appropriate FRA class and maximum permissible speed. Refer to the Federal Railroad Administration (USDOT) Track Safety Standards, 49 CFR Part 213 for detailed information on allowable track geometry. Nominal track gauge is 4 feet, 8.5 inches. The vehicle suspension system shall be designed to operate at an unbalanced curve superelevation of 4.0 inches in accordance with 49 CFR Part 213.57 (d).

All vehicles designed for use by Amtrak must safely negotiate curves with a minimum radius of curvature of 220 feet. Vehicles must safely negotiate a number 6½ frog when crossing over between tracks on 12 foot centers. Undercar equipment, diaphragms, hoses, electrical connections, coupler cut levers and other apparatus shall not be damaged or constrained from normal operation while cars and locomotives are negotiating minimum track conditions.

4.2 Catenary Wire and Third Rail

As information, the Amtrak Northeast Corridor over which its vehicles are operated use an overhead catenary power supply system to the locomotive. Operating voltages are 12,000 volts at 25 Hertz, 13,200 volts at 60 Hertz, and 25,000 volts at 60 Hertz, plus or minus 10 percent. The minimum wire height above top of rail is 15 feet, 0 inch. The vendor shall design its vehicle components in recognition of the inductive coupling effects of the catenary power system upon the metallic nature of the carbody, and possible return currents though truck components such as wheel bearings. Proper electrical system shielding shall also be applied to vehicle systems and components which may be affected by these catenary voltages.

Amtrak trains also operate in electrified third rail territory using a minimum of 600 volts DC. Third rail territory includes overrunning and underrunning third rails with wooden or composite guards and unguarded conditions. All cars approved for system-wide use must not violate the clearance requirements for third rail territory. Vendors supplying equipment for mounting undercar shall verify with the Engineer that the equipment will not contact third rail systems.

All vehicles that may operate in electrified territory that have ladders provided for access to roofs or service points as on locomotives, shall be appropriately and conspicuously marked to warn persons of the overhead wires. Normal service points such as sand fills, lights, etc. shall not require climbing on top of roofs or hoods.

4.3 Passenger Stations

As information, Amtrak vehicles are operated at passenger stations which use either high level and low level station platforms. High level station platforms have a design height of 4 feet, 0 inch above top of rail, with a minimum distance of 5 feet, 7 inches from the platform edge to the center line of the track. Low level station platforms have a design height of 8 inches above top of rail, with a minimum distance of 5 feet, 1 inch from the platform edge to the center line of the track.

4.4 Wayside Signal System

As information, Amtrak vehicles are operated over trackage with a variety of wayside signals and cab signals controlled by 100 Hertz and 200 Hertz double-rail track circuits. US&S Tru-II, GRS Phase Selective and US&S Phase Selective vital track relays are typically used. Pickup current values vary depending upon the manufacturer. Train detection at highway grade crossings is performed by audio frequency overlay track circuits. The minimum cab signal system in-rail current may be assumed to be 2.0 amperes at the entering end of a track circuit.

5.0 Vibration

All vehicle components shall be designed and mounted to have structural integrity and be operationally reliable for the vibration environment at the point of attachment and shall prevent unacceptable vibration inputs to the attachment structure. The component structure and mounting shall be designed to prevent amplification through component resonance beyond a level twice that of the attachment point. The vibration force output of any rotating component shall not exceed the vibration environment specified for the component.

When the passenger car is stationary with all subsystems operating, vertical or horizontal vibrations in any location of the car interior shall not exceed 0.10 inch peak-to-peak amplitude, and 0.01g peak acceleration from 0.1 to 14 Hertz, or 0.045 inch per second peak vibration velocity above 14 Hertz.

All carbody mounted equipment shall be designed to withstand continuous vibrations of at least 0.2 g at frequencies up to 100 Hertz in all directions, as well as randomly orientated shock loads of 5 g's longitudinally, 3 g's vertically and 3 g's laterally. Truck components located above the primary suspension shall be designed to withstand continuous vibrations of at least 6 g's at frequencies up to 100 Hertz in all directions, as well as randomly orientated shock loads of 8 g's. Truck components directly carried on the axles shall withstand continuous vibrations of at least 100 g's up to 200 Hertz in all directions, as well as randomly oriented shock loads of 250 g's.

6.0 Stainless Steel

6.1 Structural Applications

Where austenitic stainless steel is required for structural use, it shall be in compliance with the latest revision of American Public Transportation Association specification SS-C&S-004-98, Standard for Austenitic Stainless Steel for Railroad Passenger Equipment.

6.2 Non-Structural Applications

Non-structural stainless steel which will not be connected by welding, except when utilized in mechanical or electrical products, shall be AISI Types 201, 202, 301, 302, 304, 316, or 430, as applicable. The chemical compositions shall conform to the requirements of SAE J405d.

6.3 Appearance

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. Unless otherwise specified (or approved by the Engineer), exposed stainless steel shall be non-corrugated and have a 100 to 120 grit finish.

6.4 Buffing and Polishing

Buffing and polishing of stainless steel, where required, shall be done in an approved manner and without the use of any composition containing iron or iron oxide. All buffing pads and materials used for stainless steel shall not be used for buffing any other material.

7.0 Low Alloy High Tensile Steel

All low alloy high tensile (LAHT) steel shall meet the requirements of Section 4.2 of the American Public Transportation Association specification SS-C&S-034-99, revision 2, Standard for the Design and Construction of Passenger Railroad Rolling Stock.

8.0 Steel Castings

8.1 Material

All steel castings shall be manufactured in accordance with the latest revision of the Association of American Railroads Manual of Standards and Recommended Practices Specification M-201. Any steel casting used in couplers or draft gears shall meet the requirements of M-201 for Grade C, normalized and tempered.

Each casting shall be thoroughly cleaned, and all sharp or rough edges shall be removed that are as a result of the casting operation. When grinding is used to dress surface defects, or welds used to repair castings, care shall be exercised to insure that no abrupt sectional changes result. Each casting shall be identified by permanent means with its serial number and the identity of the manufacturer.

8.2 New Design Verification

To verify the design qualification of any new structural castings, one casting of each new design, selected by the Engineer from the first lot of production castings, shall be subjected to a qualification test of the casting design by the Vendor. Qualification tests shall include radiographic examination for material soundness using reference radiographs to ASTM E 446 and any mechanical testing. Acceptance levels for these radiographic examinations shall be selected by the Vendor as appropriate for the service intended, subject to the approval by the Engineer before any castings are produced. These radiographs shall meet the requirements of ASTM E 94 and E 142, and the quality level in the area of inspection shall be at least 2 percent (2-2T). A qualification test report shall be prepared and submitted to the Engineer for approval, and all associated radiographs and mechanical tests shall be made available. Once a design is qualified and accepted by the Engineer, no changes shall be made in the casting pattern, technique, heat treatment, or material composition without requalification using these procedures. If the casting selected for qualification fails to pass the test, a plan of action

including details of how failed material will be handled shall be included in the qualification test report.

8.3 Testing and Quality

All production structural castings shall be equal to or better than the design qualification castings in all respects. The casting supplier shall test, inspect, and accept castings in accordance with procedures described in AAR Specification M-201. In addition, all castings shall be subjected to both magnetic particle and radiographic inspections.

Magnetic particle inspections of all surfaces of each casting shall be conducted in accordance with ASTM E 709, by personnel certified to MIL-STD-410. With respect to structural castings, including coupler castings, the maximum permissible magnetic particle indications shall be 0.25 inch in the direction transverse to the usual direction of loading, and 0.75 inch in the direction parallel to the usual direction of loading.

Radiographic inspection of structural castings shall be conducted according to the requirements of ASTM Standards E 94 and E 142 using reference radiographs to ASTM E 446. Copies of the reference radiographs shall be submitted to the Engineer. A sampling frequency shall be proposed by the vendor and submitted to the Engineer for approval. Structural castings shall not exceed severity level 3 of ASTM E 446 in all critical areas, and shall not exceed level 5 in all other areas. During demonstration that the stated severity level requirements of ASTM E 446 have been met, successively produced castings shall be reinspected by radiography in the defective areas shown in the prior radiographic inspection. After such severity levels have been proved, the sampling frequency for structural castings shall be one casting out of each ten produced. If no castings are rejected by radiographic inspection, this frequency may be extended to one casting in 25.

A written report of the results of the tests and inspections shall be furnished for each lot of castings produced. If castings are found to be porous or otherwise unsound, the material shall be destroyed at no expense to Amtrak.

9.0 Aluminum

9.1 Material

Where aluminum and aluminum alloys are required for structural use, they shall be in compliance with American Public Transportation Association specification SS-C&S-015-99, Standard for Aluminum and Aluminum Alloys for Passenger Equipment Car Body Construction.

Carbody aluminum alloy castings may only be used for trim. Aluminum alloy castings, if used for door thresholds, shall conform to ASTM B 26, B 85, or B 108 for, respectively, sand, die, or permanent mold castings. Aluminum alloy forgings shall conform to ASTM B 247.

9.2 Coatings

All exposed unpainted aluminum components on a vehicle shall be given an anodic coating. Within the vehicle interior, any surface subject to wear and/or abrasion, such as but not limited to the luggage racks and cab trim, shall be uncolored and shall be anodized in accordance with Aluminum Association designation AA-A41. Other interior aluminum not subject to abrasion

shall be anodized in accordance with Aluminum Association designation AA-A31 if uncolored, and Aluminum Association designation AA-A44 if colored. On the vehicle exterior, all exposed unpainted aluminum shall be anodized in accordance with Aluminum Association designation AA-A41 if uncolored, and Aluminum Association designation AA-A44 if colored. Testing shall be performed on all aluminum parts to verify compliance with the specified anodizing process.

All aluminum heat transfer surfaces shall be anodized. If approved by the Engineer, heat transfer surfaces may be irradiated to Military Specification MIL-C-5541E, Class 3, followed by priming and painting, provided that this treatment can demonstrate corrosion protection equivalent to anodizing.

Painting or powder coating of exposed aluminum surfaces shall not be employed, except in unique circumstances and when approved by the Engineer, and not for surfaces subject to abrasion.

9.3 Assembly Methods

The assembly methods used for aluminum parts shall conform to the requirements of the Aluminum Company of America's Technical Report No. 524, "Specification Covering Use of Aluminum in Passenger Carrying Railway Vehicles", except as otherwise specified herein. The specific measures to be taken to prevent risk of possible electrolytic corrosion shall depend upon determination of the most suitable method which can be adapted to the design involved, and the following instructions are given for general guidance. These instructions shall not be construed to supersede conflicting recommendations by the aluminum Manufacturer.

Aluminum alloy surfaces shall not be secured to, nor make direct metal-to-metal contact with, the surfaces of copper-bearing aluminum alloy, brass, bronze, copper, lead, nickel, nickel-plated parts or alloys thereof, silver, or tin. The contact surfaces of aluminum alloy against aluminum alloy shall be coated with a zinc chromate primer before assembly. The contact surfaces of aluminum alloy against steel shall be protected with an one-part polysulphide sealant, zinc chromate primer, or a silicone sealant used as the joint compound. Alternatively, an insulating joint material which completely covers the faying surfaces may be used. The material shall be non-hygroscopic and, if fibrous, shall be impregnated with bitumen or other water-repellent substance. Some form of surface covering or insulation shall be provided for all bolts, rivets, securing clips and devices to prevent contact with the aluminum alloy, if the bolt or other device does not also consist of a compatible aluminum alloy. Carbon steel fasteners shall be hot dip galvanized or zinc plated, including washers and nuts, and where possible only the head and unthreaded portion of the shank of the bolt shall be in contact with the aluminum part when secured in place. Suitable bushings may be used. Rivets driven hot may be considered to be covered by a protective oxide coating due to the heating, but the method of riveting shall, if possible, always be with the formed rivet head in contact with the aluminum alloy. Other fastening methods must be approved by the Engineer.

10.0 Welding and Brazing

10.1 General

All welding designs and practices used shall conform to the requirements of the American Welding Society (AWS). Any requests by the vendor for substitution of other international welding codes must be submitted to the Engineer for approval on a case-by-case basis.

Requests for substitution involving welds for carbody structure (including secondary supports) are strongly discouraged.

The vendor shall be responsible for the quality of the welding and brazing done by the vendor and all subcontractors. All welders employed in the making of welds on structures or products built under this Specification must be tested to determine their ability to operate the welding equipment to be used in making the types of welds required hereunder and to produce satisfactory welds therewith.

Galvanized steel shall not be welded to stainless steel. Brazing shall not be used to join stainless steel, or to join stainless steel to other metals with the exception of copper ground plates.

10.2 Welder Qualifications

Welders employed in the making of welds on structures or products built under this Specification shall make only those welds for which they have been qualified in accordance with the requirements of AWS D15.1 or Engineer-approved equivalent. Records of welder qualification test shall be made available for review by the Engineer prior to the start of welding and during manufacturing. The qualification of welders working on truck casting repair welds, stainless steel and aluminum is of particular concern, and test qualification records shall clearly identify the exact type of weld and orientation (if applicable) for which the welder is qualified. Renewal of welder qualification shall remain in effect indefinitely unless the welder is not engaged in a given process of welding for which the welder is qualified for a period exceeding 6 months, then requalification shall be required. Production records shall identify each welder who has worked on an assembly, by assembly serial number.

10.3 Test Welds

The Engineer shall have the right to require the making of test welds to settle any question which may rise as to the suitability of any welding method or procedure used during production. AWS requirements and recommendations shall be followed in the making of tests and the settlement of other questions which may arise regarding welding practice.

10.4 Weld Preparation

Before welding is started, all parts to be joined shall be properly cleaned of coatings and films such as rust, oxide, mill scale, oil, grease, corrosion products and other foreign materials. Cleaning materials and processes shall conform to the applicable parts of Section 2 of Military Specification MIL-HDBK-132, "Protective Finishes", or approved equal. Finished welds shall present a clean appearance.

The method of base metal preparation used shall leave the welding groove smooth and uniform. Surfaces and edges to be welded shall be free from deep notches, striations, fins, tears, cracks, and other discontinuities which would adversely affect the quality or strength of the weld. Before welding over previously deposited metal, all slag shall be removed and the weld and adjacent base metal shall be brushed, chipped, or ground clean. This requirement shall apply not only to successive layers but also to the successive beads and to the crater area when welding is resumed after any interruption. Slag shall be removed from all completed welds, and the weld and adjacent base metal shall be cleaned by brushing or other suitable means.

10.5 Welding Rod

All welding rods and wire shall be purchased to conform to applicable standards, in packages of convenient size which shall be marked with the manufacturer's name and the specification, diameter and net weight of the material. The material shall be stored conforming to the AWS "Structural Welding Code" so as to protect it from damage, and so that it can be easily identified. Material shall be issued and handled in such a way as to prevent it from being mixed with that of another specification.

10.6 Structural Stainless Steel Welding

Structural welding of ferritic and austenitic stainless steel shall be governed by ASME Section IX and ASME Section VIII, Part UHA. AISI 201L and 301LN stainless steels shall be treated as P No. 8, Group No. 3 category for reference to ASME requirements.

The ferrite number for welds shall be between WRC4 and WRC10, or as proposed by the Vendor and approved by the Engineer. The weld heat-affected zones (HAZ) and weld metal shall be limited to the maximum allowable stress values in ASME Section VIII, Table UHA-23 for UNS S20100 stainless steel and Table UW-12 for rating of welds.

10.7 Other Structural Welding

All structural welding practices shall conform to the American Welding Society (AWS) D15.1 "Railroad Welding Specification" and the AWS Handbook, or other Engineer-approved standards. Requirements for dynamically loaded structures shall have precedence over those for statically loaded structures. Additional information on definitions, processes or other questions pertaining to welding shall be referred to the AWS Welding Handbooks. Welding for structural framing and sheathing on a stainless steel carbody shall be resistance and/or arc welding.

Joint welding procedures which are to be employed shall be qualified conforming to AWS D15.1 or equivalent. Written qualified welding procedures shall be prepared to provide direction for making production welds. All essential and non-essential variables, as well as all code mandated requirements, shall be incorporated in the written welding procedure specification. When the procedure is required to be qualified by test, a written procedure qualification record shall be prepared in accordance with the applicable AWS welding codes. When AWS D15.1 allows the use of prequalified joints, these joints shall conform in all respects to the provisions of the applicable AWS welding code in order to be exempt from testing.

10.8 Warpage

All parts which are to be joined by welding shall be adequately supported and held in their proper position by appropriate tables, jigs, and/or fixtures. The method of depositing weld metal shall be chosen to minimize warpage. Flanges may be stabilized during weld fabrication with bars temporarily tack welded in place, if this and subsequent removal of the temporary bars does not impair the strength of the weld-fabricated assembly.

10.9 Weld Penetration

Complete penetration welds are required for all structural welds. All complete penetration welds made from one side without backup shall be qualified by test using production welding

techniques and welders. Where partial penetration welds are proposed for Engineer approval on a case-by-case basis, the vendor shall provide design calculations supporting the penetration desired and conduct tests to prove that production welding will achieve the required penetration with an acceptable margin of safety.

10.10 Resistance Welding

Resistance welding shall be in accordance with the requirements of Military Specification MIL-W-6858, Class B for structural applications, and Class C for non-structural applications, except as noted elsewhere, and shall employ accurate control of current, time, electrode size, shape, and tip force to produce uniform welds of specified strength which are not subject to intergranular-stress-corrosion cracking. Resistance welds shall be arranged to avoid tension or "peeling" forces on the welds under any anticipated loading condition. Exposed resistance welds shall be located and arranged in regularly-spaced patterns.

Design strengths higher than standard certification and production strength requirements shall be qualified according to MIL-W-6858, Figure 11b for one thickness. Additional thickness combinations with the same increased strength ratio may be qualified by 25 spot weld shear tests plus three macrosections. Twenty of the 25 shear test specimens may be recorded from production witness tests taken from 20 consecutive production days (not calendar days). The Vendor shall submit records of the settings, ultimate shear strength, weld diameter, and weld penetration for approval by the Engineer.

Production witness welds shall be made and tested once each day and, in addition, whenever required by changes listed in MIL-W-6858. Where resistance welding is performed with multiple-schedule equipment with automated selection of resistance welding schedules (RWSs), where it is impractical to qualify selected RWS by mechanical testing before and after production welding to requirements of MIL-W-6858, all preprogrammed RWSs used for the production structure shall be qualified by mechanical test before production. Qualification structure shall be added to each production structure in an area to later be cut away (such as a window cutout). This qualification structure shall be welded with all RWSs used to fabricate the production structure. Due consideration shall be given to weld spacing, shunting effects, and other pertinent parameters. The qualification structure shall be cut away from the finished section and all of the welds mechanically tested or sectioned. Failures of test specimens shall be investigated and corrections to the production structure made as required by engineering analysis.

Surface indentation shall not exceed 20 percent of material thickness (t) or 0.01 inch, whichever is greater. However, for exterior resistance welded areas exposed to passenger view, indentation shall not exceed 10 percent of material thickness (t) or 0.005 inch, whichever is greater. For exposed welds, the vendor shall vary welding parameters and conditions within their acceptable ranges to minimize indentations. Surface burn and discoloration shall be removed by chemical cleaning, or an approved equal method, and sanding or polishing to match the surrounding surface.

10.11 Special Welding

Procedures for structural welding of stainless steel to HSLA, or other combinations of metals or conditions not covered by AWS specifications or codes, shall be submitted for review by the Engineer. Weld repair of steel castings shall be performed utilizing procedures and welders qualified in accordance with ASTM A 488. Austenitic stainless steel electrodes or wire

conforming to AWS A5.4 or A5.9 shall be used to join carbon or HSLA steels to stainless steels. Welding procedures and filler materials used with stainless steel shall not decrease the resistance to carbide precipitation and stress corrosion cracking.

10.12 Toughness

The vendor 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 minus 20 degrees F without brittle failure.

In the absence of prior operating history, and if the vendor's approved design does not require greater toughness, the minimum impact value for Charpy V-notch specimens in the coarse grain heat affected zone 1 mm from the fusion area at minus 20 degrees F shall be 15 ft-lbf of absorbed energy. The Engineer shall have the right to require impact tests to verify the specified toughness.

10.13 Finish

All welds visible to the passengers, with the exception of spot welds, shall be ground smooth. Spot welds which are visible to passengers shall be cleaned or polished to remove discoloration due to welding.

10.14 Heat Treatment

Parts which will rotate at high speeds or parts which are subjected to dynamic loading, such as trucks, end underframes, and other critically-stressed parts, shall be heat treated after welding for stress relief and/or strength attainment where appropriate. Stress relief shall be performed in accordance with the applicable AWS Code and ASTM specification for the material involved, or the recommendations of the material manufacturer.

10.15 Brazing and Soldering

All brazing (conducted above 840 degrees F) and non-electrical soldering (conducted below 840 degrees F) shall be in accordance with the requirements of the AWS Welding Handbook, Volume 2, latest issue. Procedures and personnel who do brazing work shall be qualified in accordance with AWS B2.2-85, Standard for Brazing Procedure and Performance Qualification. Procedures and personnel who do torch soldering shall be qualified through the preparation and approval of test samples of production torch soldering. Brazed or soldered joints shall present a first-class appearance in accordance with AWS quality standards. All pipe or tubing connections shall be leak-free. All pneumatic system, air brake and air conditioning system brazing and soldering must be performed with the piping being purged with nitrogen to prevent the formation of any oxidizing contaminants during and after brazing or soldering operations have been completed. Any soldering of stainless steel lap joints on a carbody shell shall have a smooth, uniform appearance and shall be leak-free.

10.16 Inspection

All welding inspections shall be performed in accordance with the requirements of the applicable AWS Code, under the supervision of an AWS-certified welding inspector. Critical structural weld locations shall be submitted to the Engineer and shall be inspected to quality level No. 1,

and non-critical structural welds shall be inspected as a minimum to quality level No. 3, in conformance with ASTM E 390. In addition to visual inspection requirements specified by applicable AWS welding code, nondestructive surface inspection (dye penetrant or magnetic particle methods, as appropriate) shall be used to inspect all first production welds.

Radiographic inspection of welds, where required, shall be performed in accordance with ASTM E 94. Magnetic particle inspection of welds, where required, shall be performed in accordance with ASTM E 709. Dye penetrant inspection of welds, where required, shall be performed in accordance with ASTM E 165. Ultrasonic inspection of welds, where required, shall be performed in accordance with ASTM E 164. Any vendor request for substitute tests must be submitted on a case by case basis for approval by the Engineer.

10.17 Vendor Documentation

Before any structural welding takes place, the vendor shall submit to the Engineer upon request written procedures, including welding procedure data sheets for each production weld and all quality assurance measures including inspection, welder qualification and defect repair procedures conforming to the applicable AWS welding code.

For structural welding, the following deliverables shall be furnished, all conforming to applicable standards:

a) Welding Procedure Data Sheet.
b) Records of welding qualification tests.
c) A completed "Report" for any non-destructive testing of welds, if required.
d) Resistance welding test reports.

11.0 Joining and Fastening

11.1 General

The vendor shall minimize the number of different sizes and styles of fasteners and moldings used. Unless otherwise approved by the Engineer, all fasteners shall be inch-standard commercially-available components and use standard US hand tools for installation, and shall comply with Amtrak Specification 706, revision A, "Threaded Fasteners". All fasteners shall conform to the requirements of all applicable laws, rules and regulations, including, but not limited to, the "Fastener Quality Act" and Federal Title 15 USC Section 5401, et seq. All fasteners used to secure access covers or panels to equipment boxes or interior panels shall be made captive to the panel in which they are used.

All joints shall be designed to permit tool access and fastener removal during disassembly. When bolts are used to attach equipment and either the bolt head or nut is inaccessible, a sturdy reusable mechanical locking device shall be used to prevent the bolt head or nut, respectively, from turning during installation or removal. No protruding screws, mounting bolts or similar items shall be permitted either on the interior or exterior of the vehicle, other than those appointments which can be built into the structure in no other manner, as determined by the Engineer. No self-tapping screws shall be used in areas where dismantling can normally be expected more frequently than once in every ten years. Self-locking nuts shall be elastic stop nuts or approved equal and shall be used throughout where practical. Stainless steel screws or bolts, flat washers, lock washers and high-temperature self-locking nuts shall be used

in mounting and in making connections to electrical resistors and other heat-producing apparatus. All lock wire shall be stainless steel.

Flat washers shall be used on both sides of all bolted connections (that is, under the bolt head and under the nut) unless otherwise approved by the Engineer. The use of non-captive conical spring washers is prohibited. Where Society of Automotive Engineers (SAE) standard J429 Grade 5 or above fasteners are applied, or their equivalent, the washer shall be hardened. At least 1.5 screw threads, but not more than 8 screw threads, shall be visible beyond all nuts.

All joints shall be properly aligned, tight and durably constructed, whether exposed or concealed. When not otherwise specified in drawings or specifications, gaps between joints shall be held to a dimension not greater than 10 percent of the thinner material being joined, or 0.002 inch, whichever is greater. Drill jigs shall be utilized to ensure interchangeability of fabricated parts and components. Gaps shall be uniform in width. The edges of panels shall have a smooth, finished appearance.

Certain combinations of materials require particular care in joining to avoid the possibility of corrosion. Isolating and moisture-resistant materials, appropriate to the materials being joined, shall be used at all times. Plastic screws, bolts nuts or other such fastening components shall not be used except where approved on an individual item basis by the Engineer. Joints shall be designed to drain free of moisture, and in a manner to prevent the accumulation of debris. Star-type internal or external toothed washers shall not be used except where stated otherwise.

11.2 Exterior Fasteners

Any fastener used on the underside of a vehicle, or used to attach any equipment or apparatus to the vehicle exterior or roof except as noted below, or used on the trucks, shall have a minimum bolt diameter of 0.375 inch and meet the requirements of either the Society of Automotive Engineers (SAE) standard J429 for Grade 5 (zinc-plated), Grade 5.2, Grade 8 (zinc-plated) or Grade 8.2, or the International Standards Organization (ISO) Standard 3506 Edition 2 for Grades A2-80, A4-80 or C3-80, and shall be used with corresponding strength nuts. All fasteners used on the roof, or exposed on the sides or ends of the vehicle, shall be stainless steel.

The application of all exterior fasteners and the sizing of mountings and attachments of underfloor, exterior, roof or truck mounted equipment, equipment supporting structures or brackets, etc. shall be based upon the yield strength of SAE J429 Grade 2 bolts (and Class A nuts). In all cases, however, the minimum grade fastener which can be applied is either SAE J429 Grade 5 or 5.2, or ISO Grade A2-80 or A4-80. No underfloor equipment weighing over 50 pounds shall be supported solely by fasteners.

11.3 Interior Fasteners

All fasteners visible to the passengers on the inside of the car shall be stainless steel. All fasteners not visible to the passengers on the inside of the car shall be either stainless steel, zinc-plated steel or cadmium-plated steel, as appropriate to the materials being joined.

11.4 Removable Panel Fastenings

All removable panels and access hatches within a car interior shall be secured with Southco, Inc. Number 17 or approved equal quick opening slotted head captive screw fasteners of

stainless steel with thermoplastic washers. Properly installed stainless steel screw retainers shall be used. Stainless steel matching receptacles riveted or welded in place shall be used. No clip-on or press-in type of receptacles shall be employed. In locations approved by the Engineer, Southco, Inc. number 9 or 12 fasteners along with nylon wear washers may be used.

11.5 Thread Standards

Fasteners shall use unified inch screw threads conforming to ANSI B1.1 (UN and UNR thread form), or metric screw threads conforming to ANSI B1.13M. Square and hex bolts and screws shall conform to ANSI B18.2.1. Machine screws shall conform to Federal Specification FF-S-92.

11.6 Plating of Fasteners

All fasteners that are not stainless steel shall be plated with cadmium or zinc as specified. All plated hardware in contact with heat producing apparatus shall be plated with zinc. Cadmium plating shall conform to the latest revision of Federal Specification QQ-P-416B, Class 2 or 3, Type II. Zinc plating shall conform to the latest revision of ASTM B 633, Type II, Service Condition SC1 through SC4 for threaded fasteners.

All fasteners used in structural or safety-critical applications which are plated or chemically cleaned shall have certifications verifying freedom from hydrogen embrittlement. If these fasteners are plated by other than the original manufacturer, a representative sample of these fasteners, as agreed to by the Engineer, shall be tested for hydrogen embrittlement by the Vendor or a supplier following ASTM F 519 procedures. An ASTM F 606 wedge test sample may be used in place of the F 519 standard samples. Test loads shall be a minimum of 80 percent of yield strength or proof load, and held for a minimum of 168 hours. Any failures shall result in rejection of the entire lot.

11.7 Torquing

All fasteners shall be properly torqued. All torque values used by the vendor and its suppliers, and all torque values given in all manuals, shall by "dry" (i.e., non-lubricated) torque values. All fasteners used in structural or safety-critical applications, including underfloor, truck and roof fasteners, and all fasteners exposed to fatigue loads shall be torqued to a minimum preload equal to 75 percent of their proof load, and then neatly "torque striped" after torquing by paint or other approved means to visually indicate proper torquing. All other fasteners shall be torqued to a value appropriate to the application, so that they do not loosen in service.

Fastener installation torque for standard oiled or waxed bolts with standard or heavy hex nuts may be calculated from IFI Fastener Standards' equations using values for "K" of 0.18 for unplated and 0.15 for plated threads. Locknuts shall be torqued in accordance with their manufacturer's recommendations or the vendor may conduct tests to determine installation torque. For those nuts or bolts requiring "torque striping", the Engineer may require bolt torque-tension tests to verify that installed preload is equivalent to 75 percent of proof loads.

11.8 Rivet and Bolt Holes

Rivet holes and bolt holes shall be accurately located and aligned, and when necessary holes shall be reamed round to specified size in position. Bolt hole clearances shall not exceed the Industrial Fasteners Institute's requirements. Hand driven steel rivets shall be driven hot, and

may be driven cold when adequate mechanical equipment is used. Heads shall be concentric with the shank of the rivet. Exposed heads shall be free from rings, fins, pits and burrs. Any rivet which is removed shall be replaced with the next larger size rivet, after reaming the hole to the appropriate size.

11.9 Swage Locking Fasteners

"Huck" (swage-locking) fasteners, or equivalent, conforming to Military Specification MIL-P-23469 may be used in locations approved by the Engineer. All rough surfaces of the collar end of these fasteners shall be machined or ground smooth where accessible to passengers, crew, or maintenance personnel performing routine maintenance functions.

11.10 Joint Fitting

Joints shall be properly fitted, whether exposed or concealed. Metal shims (of the same metal as the parts being joined or fastened) may be used, when approved by the Engineer on a case-by-case basis, to remedy minor misalignments or gaps at connections. Shims shall be welded in place, and the stack-up shall not exceed 0.25 inch overall thickness. Epoxy and other plastic fillers shall not be utilized.

Where metal is riveted or bolted to metal in the vehicle structure, contact surfaces shall be free of dirt, grease, rust and scale and shall be coated with a metal base primer conforming to Federal Specification TT-P-664. Stainless steel parts shall not be coated. Where wood and ferrous metal surfaces are placed together, the wood is to be coated with aluminum paint conforming to Federal Specification TT-P-0038, and the metal, except stainless steel, is to be coated with a zinc chromate primer. Where wood and wood are placed together, both abutting surfaces shall be coated with aluminum paint conforming to Federal Specification TT-P-0038.

Any joint which is secured by mechanical fasteners and which is not in the vehicle interior shall be made weather resistant by means of a minimum 10 year life neoprene gasket, which shall be die cut unless otherwise approved. The use of sealants or adhesives in such applications is prohibited. Whenever a permanent joint in the carbody is to be made weather resistant, an approved cleaner-primer for silicone sealants must be used, followed by an approved silicone sealant which shall be neatly applied.

11.11 Locking Compounds and Sealants

Devices and components which rely on thread-locking and sealing compounds to make them function safely and reliably, or which require the use of such materials to make their assembly and function possible, shall not be provided. Exceptions may be made by the Engineer upon the submission of sound technical grounds for their employment. Such materials may be used for applications that are a permanent part of the vehicle or component where no disassembly will be required for the service life of the vehicle or component.

The use of locking compounds or liquid thread sealants on any threaded fastener which must be disassembled more often than at the time of complete component overhaul is prohibited. The use of any such compound shall be submitted to the Engineer for approval on an individual item basis. Use of any locking compounds, liquid thread sealants or anti-seize compounds on threaded electrical connections is prohibited except where approved on a case-by-case basis by the Engineer.

11.12 Equipment Hardware and Shields

All exposed hinges, hinge pins, latches, nuts, bolts, washers, springs and other hardware on equipment boxes and cases mounted outside the carbody shall be made of stainless steel, as well as any heat, splash or debris shields except where otherwise permitted.

12.0 Carbody Materials

12.1 Trim Finish

All exposed passenger car or cab interior metal trim shall have a 100 or finer grit brushed satin finish. Aluminum trim may have a glass beaded satin finish. All exterior stainless steel surfaces shall have an approved finish as specified in Section 6.3.

12.2 Lumber

Lumber shall be thoroughly air seasoned or kiln dried before use, dressed on all surfaces to full dimensions and treated to meet the flammability requirements of Section 2.

12.3 Plymetal

All plymetal and metal faced plywood panels shall conform to Military Specification MIL-P-8053, Type III. The panels shall be composed of double-sided plymetal, using APA Specification PS-1, Grade Structural I, exterior grade A-B or better plugged five-ply plywood, using resin glued hardwood or Douglas fir with solid and jointed cores and crossbands, faced on both sides with 0.016-inch thick AISI 200 or 300 series stainless steel. The use of balsa wood or other alternates is prohibited. The stainless steel skin shall be securely bonded to the plywood, and the edges sealed from moisture entry using epoxy or urethane paint. All exposed panel edges and holes, such as openings for conduits and joints between panels, shall be waterproofed and sealed in an approved manner. Special attention shall be given to resistance of damage from presence of brine or acidic car-cleaning liquids.

12.4 Composite Panels

12.4.1 Description

All composite panels shall be of a design with a proven history of prior successful service on North American rail passenger vehicles. Use for other than floor panels shall be approved by the Engineer. Composite panels shall be of a foam core sandwich design, consisting of upper and lower fiberglass fabric reinforced skins impregnated with a thermosetting resin, affixed to a structurally reinforced, closed cell rigid foam core material. If parallel strip reinforcement is used, it shall run perpendicular to the supporting floor beams of the vehicle's structure. A nonhydroscopic, fiberglass reinforced, resinous syntactic material shall be used for perimeter edges, hardware and insert applications and framing cutouts for all penetrations. Top and bottom skins shall form a homogeneous bonded edge with the resinous perimeter material such that the outer skins will never delaminate during the removal of floor covering material.

Each individually placed panel shall be so designed that openings and penetrations are precut during the manufacturing process to allow simple replacement for like panels installed within the vehicle configuration. "DO NOT SAND" signage in six areas on the top side of each panel shall

be included within the phenolic resin of the top layer skin in such a manner as not to effect the panel design characteristics.

The panel design configuration shall be manufactured to exceed the structural requirements needed for application with the vehicle for deflection and AW3 loading by a minimum of 20 percent. This design requirement shall be included in formulations associated with panel testing where applicable. Composite panels shall meet the smoke and flammability requirements of Section 2, and in addition the following requirements:

- when tested to ASTM E162-98, the maximum $I_S \leq 5$. No flaming or dripping pieces are permitted.

- when tested to ASTM E662-97, the following maximum values shall be obtained:

D_S (1.5) 0.4 (non-flaming) D_S (1.5) ≤ 4.5 (flaming)
D_S (4.0) 16.5 (non-flaming) D_S (4.0) ≤ 55.4 (flaming)

- when tested to ASTM E119-98, a floor panel sample shall pass all test criteria and achieve an endurance rating of 15 minutes, and in addition shall not exceed a surface temperature of the unexposed side (top surface) of 120 degrees F during the test.

Repair procedures for composite panels shall be provided in the maintenance manuals. This shall include impact damage, cracks, localized delaminations, surface sheet finish repairs from abrasion and impact, and repair/replacement of mechanical insert fasteners. A detailed special tools list for repairs shall be included in the document.

12.4.2 Load Testing

The following tests shall be conducted on a representative composite flooring panel which shall be supported on beams that are equal to the longest distance between support spans found within the carbody floor structure. Production configuration leveling tape and fasteners shall be used to simulate the actual floor installation, but no floor covering shall be applied. For all test conditions, there shall be no visible or audible indications of delamination of the panel skin from the core, no puncture or damage to fibers of the panel surfaces, no separation of any internal web from the top or bottom skin, and no degradation, cracking or fracture of the foam core, except where so identified. Test panels shall be sectioned to verify internal conditions.

Floor Deflection Test

The test panel shall successfully withstand a uniformly distributed load of 60 pounds/square 2foot. The maximum surface deflection under load shall be less than 1/250th of the span. Permanent deformation of the top surface shall be less than 0.010 inch.

Indentation Resistance Test

The test panel shall successfully withstand a concentrated load of 300 pounds applied to a 0.375 inch diameter area having a 0.0625 inch radius on the bottom edge. Permanent deformation of the top surface shall be less than 0.010 inch

Maximum Load Test

The test panel shall successfully withstand a distributed load of 200 pounds per square foot, covering an area approximately 3 feet 6 inches wide, applied so that the load is evenly distributed starting in the unsupported area adjacent to the panel's end connection, then extending over a single supporting member and the next adjacent unsupported section of the panel. Permanent deformation of the top surface shall be less than 0.010 inch.

Rolling Load Test

The test panel shall successfully withstand the loading of a 2-wheeled or 4-wheeled cart with a load of 200 pounds per wheel, which shall be rolled on the panels laterally, longitudinally, and in a circular path with a 2 foot radius. The wheels shall be 3 inches in diameter, 1 inch wide with a 0.125 inch radius on each edge and a Shore A80 durometer hardness. Permanent deformation of the top surface shall be less than 0.010 inch.

Small Object Impact Test

The test panel shall successfully withstand a 16 pound spherical weight, 8.5 inches in diameter, being dropped from a height of 60 inches. Two drops shall be performed, the first in the mid section of the long span sample and the second in the mid section of the shorter span sample, each 12 inches from the edge of the panel. For both tests, the permanent deformation of the top surface shall be less than 0.095 inch. While localized separation of internal webs from the top or bottom skins is allowable, this damage shall not exceed 10 inches in diameter and shall not propagate beyond the outermost adjacent web or parallel to the damaged webs, when subjected to passenger loading. Localized fracture of the foam core shall be permitted.

Large Object Impact Test

The test panel shall successfully withstand a 150 pound weight, having a 3 inch by 8 inch contact area, being dropped from a height of 12 inches. The contact area shall have a minimum hardness of Shore D70, a thickness of 0.25 inch, and shall be machined flat within 0.060 inch. Two drops shall be performed, the first in the mid section of the long span sample and the second in the mid section of the shorter span sample, each 12 inches from the edge of the panel. The long axis of the contact area shall be parallel with the support beams. For both tests, the permanent deformation of the top surface shall be less than 0.125 inch. While localized separation of internal webs from the top or bottom skins is allowable, this damage shall not exceed 18 inches in diameter and shall not propagate beyond the outermost adjacent web or parallel to the damaged webs, when subjected to passenger loading. Localized fracture of the foam core shall be permitted.

Dynamic Load Life Cycle Test

The test panel shall successfully withstand 1,000,000 load and release cycles of a 200 pound weight having a 3 inch by 8 inch contact area, applied directly over the mid span, 6 inches from the edge. The long axis of the contact area shall be parallel with the support beams. The contact area shall have a minimum hardness of Shore D70, a thickness of 0.25 inch, and shall be machined flat within 0.060 inch. Following the test, permanent deformation of the top surface shall be less than 0.010 inch. The panel shall have less than 0.188 inch deflection when a uniformly distributed load of 60 pounds per square foot is applied when the panel is supported on beams spaced 22 inches apart.

12.4.3 Insert Testing

The following insert tests shall be performed on a representative composite flooring panel sample, consisting of the installation of two 1/4"-20 UNC threaded inserts and two 5/8"-11 UNC threaded inserts applied to the solid core resinous syntactic material.

Torque Test

Both 1/4"-20 UNC threaded inserts shall withstand a torque load of 75 lb.-in., and both 5/8"-11 UNC threaded inserts shall withstand a torque load of 100 lb.-ft., without rotation of the inserts or damage to the panel.

Tensile Test

Both 1/4"-20 UNC threaded inserts shall withstand a tensile load applied perpendicularly to the panel surface of not less than 250 pounds, and both 5/8"-11 UNC threaded inserts shall withstand a tensile load applied perpendicularly to the panel surface of not less than 500 pounds. No cracking or structural failure shall occur.

Shear Strength Test

Both 1/4"-20 threaded inserts shall withstand a shear load applied parallel to the panel surface of not less than 450 pounds. No cracking or structural failure shall occur.

12.4.4 Floor Covering Removal Testing

The following test shall be conducted on a representative composite flooring panel which shall have the approved rubber floor covering applied using the approved adhesive. During the installation process, all bubbles shall be rolled out and the exposed ends clamped to the panel to assure the highest bond possible. To verify the panel strength, after the adhesive has been totally cured, a tool shall be used to lift a corner edge and separate the floor covering from the panel surface, for a minimum depth of 3 inches for a distance of 2 feet along both side edges of the panel. This test shall be repeated at an adjacent corner of the panel. In both cases, the top skin of the panel must not delaminate from the panel's edge when being rolled back from the edge in a "cold roll" fashion.

To verify the proposed rubber floor covering removal technique identified in the Maintenance Manuals, the floor covering shall be removed at the opposite end of the test panel using the recommended technique. No delamination shall occur. Continue removing any remaining adhesive to simulate preparing the composite panel for new floor covering. No damage shall occur to the panel finish during the adhesive removal process.

12.5 Plywood

All plywood shall be manufactured to conform with the requirements for Group 1, Exterior or Exposure 1 durability of U.S. Product Standard PS1/ANSI A199.1 for construction and industrial plywood, and then stored under cover. All plywood panels shall be sealed with aluminum paint on all edges and cutouts as soon as possible after fabrication. All exposed edges of the panels, joints between panels, fastener heads and openings of panels used in areas accessible to moisture shall be waterproofed and sealed at the time of application.

12.6 Melamine-Faced Aluminum

Melamine-faced aluminum panels shall be constructed by laminating melamine to aluminum sheets. The melamine-impregnated papers shall be directly molded to the aluminum sheets at temperatures of no less than 270 degrees F and pressures no less than 1000 pounds/square inch. The melamine shall have a low gloss, matte finish. The surface characteristics, after manufacture, shall be no less than that required of type GP (General Purpose) in NEMA Standard LD 3. The melamine and the required binder sheets shall be 0.015 inch thick plus or minus 0.004 inch. The aluminum sheet shall be a minimum of 0.025 inch thick when used as facing on plywood, and a minimum of 0.081 inch thick when not laminated to a solid substrate such as plywood. The aluminum sheets shall be properly cleaned by etching, sanding or other approved process to insure full and acceptable adhesion. The use of contact adhesives to bond the melamine sheets to the aluminum backing is prohibited. The bond between the melamine and aluminum sheets shall, at a minimum, meet the following requirements:

Mechanical Property	ASTM Test	Requirements
Internal bond	D 952	2,600 lbf/in^2
Flexural strength - (S)	D 790	with grain: 26,500 lbf/in^2 crossgrain: 25,300 lbf/in^2
Modulus of elasticity - (E)	D 790	with grain: 2.8×10^6 lbf/in^2 crossgrain: 3.1×10^6 lbf/in^2
Tensile strength	D 638	with grain: 22,300 lbf/in^2 crossgrain: 20,300 lbf/in^2

12.7 Fiberglass Reinforced Plastic

All fiberglass reinforced plastics (FRP) shall be a polymeric-reinforced, laminated material consisting of a gel-coated surface, fiberglass reinforcement and a polyester resin. Coloration of FRP shall be achieved through pigmentation of the gelcoat or application of a DuPont Tedlar polyvinyl fluoride (PVF) composite laminate. FRP shall not be painted, unless otherwise specified. They shall be lightweight, high strength products with fire retardant and smoke properties meeting the requirements of Section 2, and shall be designed for the specific application on the vehicle. Colors used shall be approved by the Engineer. All interior applications shall be designed such that the surfaces exposed to passenger view shall not crack, chip, peel, fade or otherwise be damaged from conditions encountered in service. Any repairs made to FRP due to accidental damage shall be made by repair of the gelcoat and not by painting.

Fiberglass reinforced plastic shall be manufactured by either open molding, hand layup, spray layup or by matched die molding. Minimum panel thickness shall be 0.12 inch. Glass fiber reinforcement shall be distributed uniformly throughout to avoid either resin-rich or resin-starved areas. All attachment points, points of flexure and edges shall be suitably increased in cross-section to provide proper reinforcement. Designs using wood reinforcement shall make proper allowance for its absorption of resin. Dies and molds shall be designed to take into account any "spring back" of the part's shape, so as to achieve correct final dimensions. All corners and edges shall be rounded; there shall not be any sharp edges allowed on any parts. The

minimum curve radius and draft angle of FRP molds shall be demonstrated as appropriate for the manufacturing process selected by evidence of experience of the fabricator with the minimum radius and draft angles proposed.

The resin shall be a commercial grade material, selected in accordance with the physical properties required and the manufacturing process utilized. All fillers and additives shall be added to resin mixes in accordance with the supplier's recommendations. The fiberglass reinforcement shall be mat, fabric woven roving, continuous roving, chopped spun roving or swirl mat as required. Finished fiberglass reinforced plastic items shall have a minimum fiberglass reinforcement content of 22 percent by weight. The gelcoat for all fabrication processes, except compression molding, shall be ISO NPG type, impact-modified, resistant to scuffing, fire, weather, cleaning agents, graffiti and perspiration without damage or adhesion failure, and shall have a minimum thickness of 0.015 inch. Antimony trioxide shall not be used as a resin additive. The color of compression-molded parts shall be achieved by the Sherwin-Williams in-mold coating process, or in-mold application of a DuPont Tedlar polyvinyl fluoride composite laminate. The in-mold coating shall be considered the gelcoat and shall be impact-modified and be resistant to scuffing, fire, weather, cleaning agents, graffiti and perspiration without damage or adhesion failure, and shall have a minimum thickness of 0.010 inch. The resin shall be color matched to the in-mold coating or DuPont Tedlar polyvinyl fluoride composite laminate.

All fiberglass reinforced plastic items used in the vehicle shall conform to the following requirements. Test specimens shall be cut from test plaque samples, conditioned in accordance with ASTM D 618 and tested by an independent laboratory. The average value of five tested specimens in each category shall conform to the specified minimum. None of the five specimens shall have a value less than 80 percent of the specified minimum:

Mechanical Property	ASTM Test	Requirements
Tensile Strength, minimum	D 638	10,000 psi
Compressive Strength, minimum	D 695	18,000 psi
Flexural Strength, minimum	D 790	15,000 psi
Impact Strength, minimum	D 256	10 ft-lbs per inch of notch
Hardness, minimum	D 2583	45 Barcol
Visual Defects, minimum	D 2563	Level II

12.8 Tedlar Composite Laminate

DuPont Tedlar polyvinyl fluoride (PVF) composite laminate incorporating DuPont Teflon surface protection may be used over fiberglass reinforced plastics (FRP), thermoplastics, aluminum panels or other interior surfaces to provide a low gloss textured stain, graffiti and UV resistant, multicolored pattern or solid colored finish. The laminate shall be a Schneller GT series composite laminate, or approved equal, consisting primarily of a DuPont Tedlar top coat with Teflon surface protection and one or more integrally pigmented color plies, with a finished overall thickness of 0.010 to 0.035 inch.

When applied to three dimensional thermoplastic surfaces, the laminate shall be pressed to the plastic sheets prior to vacuum or pressure forming, using GT TRIM T series materials. When applied to three dimensional compression-molded FRP, the laminate shall be applied using an "in-mold" process, i.e. thermoformed and installed into the FRP mold prior to the molding of the part, using GT Form series materials.

When applied to flat or single curvature surfaces, the laminate shall be applied by hand to fiberglass-reinforced plastics (FRP), thermoplastic sheet, aluminum panels or other interior surfaces using a manufacturer-approved pressure sensitive or contact adhesive, or under heat and vacuum using a manufacturer-approved heat activated adhesive. All Tedlar-faced decorative laminate edges shall be either cut flush and mechanically captured by other surfaces or trim, or wrapped under the substrate with a minimum return of 0.75 inch, or as recommended by the manufacturer. GT TRIM F2000T series materials or fiberglass-reinforced GT TRIM G2002T series continuous roll form laminates shall be selected depending on damage resistance and geometry requirements. All fabrication details, application methods, designs, colors, textures, and appearance shall be approved by the Engineer.

12.9 Seat Cushions

REFER TO SPECIFICATION **665** Seat Cushion Assemblies

12.10 Seat Upholstery Material

REFER TO SPECIFICATION **665** Seat Cushion Assemblies

12.10.1 Woven Fabrics

REFER TO SPECIFICATION **665** Seat Cushion Assemblies

12.10.2 Vinyl Upholstery

REFER TO SPECIFICATION **665** Seat Cushion Assemblies

12.11 Glazing Material

All glazing material and applications shall be in accordance with 49 CFR Parts 223, 238.113 and 238.221. All windows shall be marked in accordance with FRA requirements, and shall also include the manufacturer's name and manufacturing date. All laminated glass shall use a plasticized polyvinyl butyl resin membrane resistant to ultraviolet and visible light and heat. All glazing, including color and tint, shall be approved by the Engineer prior to production.

Any Cab car or locomotive cab Operator's windshield shall be an Engineer approved electrically heated triple laminated glass rail vehicle windshield. The inner surface shall be a glass spall shield. It shall have an internal continuous transparent electrically conductive polyester film or pyrolytic tin-oxide fused coating to provide windshield defrosting with a minimum power density of 0.5 watts per square inch, plus or minus 20 percent. There shall not be a film joint in the central area of Operator vision. The electrical wiring connections shall be on the inside of the glazing. Each Operator windshield shall comply with all FRA Type I requirements, the optical quality requirements of Article 5.15 of ANSI Z26.1, and the requirements of the Association of American Railroads Manual of Standards and Recommended Practices RP-500, Appendix A.

All edges and radii of glazing shall be ground smooth and be free of burrs and sharp edges which could damage elastomeric materials. The overall dimensional tolerances of individual pieces of glazing shall meet the requirements of ASTM C 1036, Table 1. All glazing shall be resistant to ultraviolet and visible light and heat to inhibit fading and loss of properties due to extended exposure to direct sunlight. Within types of glazing used, there shall be no appreciable variation in color in the individual windows when examined over a white background. For laminated glass, when an individual piece of glass is laid on a truly flat surface, the glass shall not indicate a bow of more than 0.0625 inch per linear foot. The overlap of one sheet of glass of a glass laminate with respect to the other at an edge shall not exceed 0.0625 inch. No laminated glazing containing unbonded areas shall be accepted.

Polycarbonate glazing shall consist of Engineer-approved abrasion resistant polycarbonate rail vehicle glazing material. Individual pieces of polycarbonate glazing shall bow no more than 0.031 inch per linear foot when tested on a truly flat surface plate. Optical quality of polycarbonate glazing shall conform to the requirements of Article 5.15.2.2 of ANSI Standard Z26.1. Average visible light transmission through untinted polycarbonate glazing shall not be less than 82 percent in 0.25 inch thickness, and 78 percent in 0.5 inch thickness. All polycarbonate glazing shall comply with Test No. 10, Article 5.10 of ANSI Standard Z26.1. The protective covering shall be marked to indicate the orientation of the extrusion "rolling axis" for installation. Glazing shall be installed in the vehicles with this axis horizontal.

12.12 Rubber Floor Covering

All application of rubber floor covering shall be an Engineer-approved high quality slip resistant (per 36 CFR Part 1192 Appendix I) transportation grade rubber sheet flooring, designed for rail vehicle usage, and available in rolls. The floor covering shall contain a nominal 20 percent (by weight) of butadiene styrene rubber, shall be non-staining, non-discoloring, and completely non-oil extended. Only high quality hard clay shall be used as the filler. No whitening (limestone) shall be used in the compound. The floor covering shall meet the smoke and flammability requirements of Section 2, and shall have an anti-slip surface that is capable of developing a coefficient of friction of 0.60 in the dry state, as determined by ASTM D 2047. The color shall be a low gloss shade approved by the Engineer. Color and any marbling shall run completely through the material. All marbling shall be well developed and consistently located throughout

the floor covering, and shall not contain heavy concentrations which result in large blotches, spikes or other noticeable abnormalities. At 70 degree F temperature the floor covering shall be capable of being bent around a 0.75 inch diameter mandrel without breaking, cracking, crazing, or showing any change in color. The floor covering thickness when pieces are butted together must be exact, and no bumps, raised edges or other inconsistencies shall be permitted. The flooring material shall be fully homogeneous throughout, and shall meet the requirements of Federal Specification SS-T-312.

The back of the floor covering shall be sanded to a coarse grit roughness, and shall be installed with proper allowance for expansion, and in accordance with the manufacturer's recommendation. The flooring adhesive system utilized shall not result in damage to any composite subfloor panels when flooring is removed, and be warranted to prevent the flooring material from lifting off the subfloor for a period of no less than 15 years. All seams not bordered with waterproof adhesive on both sides shall be sealed with a cold weld compound, in accordance with the manufacturer's recommendations. All flooring materials and installation adhesives shall be unaffected by moisture, salts, dirt, grit, tar, oils, floor soaps, de-icers and the like. No sanding or reworking of the floor covering visible surface that changes the matching characteristics of the original material shall be permitted.

13.0 Elastomers

13.1 General

All elastomeric parts shall be so compounded and cured that they will perform satisfactorily during operation at any ambient temperature from minus 40 degrees F to 175 degrees F and shall have a minimum of 10 years in-service life consistent with obtaining the other characteristics specified. All elastomers shall be of neoprene (chloroprene), silicone, or approved equal, unless otherwise specified or approved by the Engineer, be ozone resistant and contain a minimum amount of process oil or reclaimed rubber. Motor and other resilient mounts shall be made of natural rubber where not exposed to oil, ozone or sunlight, and shall be chloroprene (neoprene) otherwise. Where applicable, assembled elastomeric components shall be sufficiently pre-loaded so as not to be totally relieved by the combined effects of maximum service loading and permanent set. Unless specifically approved by the Engineer, the joining of elastomeric pieces shall be conducted by the hot vulcanization process only. Alternative bonding procedures will be evaluated by the Engineer on a case-by-case basis. The thickness and hardness of elastomers used in truck assemblies and other applications subjected to water shall not vary by more than 5 percent when measured in accordance with ASTM D 395, Method B, with test conditions of ASTM D 3137, 96 hours at 185 degrees F, with water as the liquid medium. All elastomers shall conform to the requirements of ASTM C 542 and meet the smoke and flammability requirements of Section 2.

13.2 Bonded Parts

For all parts made by curing elastomers to metal, any premature failure (less than 10 years) between metal and cement or cement and elastomer occurring when the part is used in normal service, and according to the provisions of this Specification, shall be considered as caused by a defect of material and/or workmanship.

13.3 Metal Parts

Any steel part to which neoprene or other approved material is cured shall be made with AISI type 1020 or 1045 hot-rolled steel, of a quality suitable for brass plating after pickling. The strength of any elastomer-to-metal bond shall exceed the tensile strength of the elastomer, when tested in accordance with Method A of ASTM D 429.

13.4 Truck Parts

Truck bumpers and snubbers shall be made of natural rubber or approved equal. They shall be resistant to abrasion, oil, grease, acid, car wash solutions, steam cleaning and paints. Exterior surfaces of air springs shall be abrasion resistant natural rubber, and shall not self-abrade. Girdle rings shall be molded integral rubber for abrasion resistance. The compression set for elastomers used in truck assemblies shall be less than 10 percent when measured in accordance with ASTM D 395, Method B, for 22 hours at 158 degrees F in air.

13.5 Carbody Parts

Glazing strips shall be of black neoprene (chloroprene) or approved equal material, conforming to ASTM C 542. Door seals shall be of neoprene or approved equal material and shall be free of defects in material and workmanship. The durometer hardness measured with a Shore Type "A" durometer at a temperature between 70 and 90 degrees F shall be 70 plus or minus 5.

13.6 O-Rings

For other than the air brake system, all O-rings shall be of commercially available sizes, and one mounting surface of each O-ring application shall have a machined mounting seat of sufficient depth to positively hold the O-ring in place during assembly. Other configurations must be approved by the Engineer.

14.0 Piping

14.1 General

All piping, valves, fittings, installation methods and testing shall be in accordance with the latest edition of the Code for Pressure Piping, ANSI B31.1. Joints in a straight run of pipe, which serve the sole purpose of connecting pipe lengths, shall not be used unless approved by the Engineer. Single pipe lengths shall be as long as possible. All bends shall be unwrinkled.

All pneumatic system, water system, air brake and air conditioning system brazing and soldering must be performed with the piping being purged with nitrogen to prevent the formation of any oxidizing contaminants during and after brazing or soldering operations have been completed. After fabrication, all water, refrigeration and air system piping shall be cleared of all dirt and foreign matter, flushed with a degreasing agent, and dried in accordance with a written procedure approved by the Engineer. After cleaning, all piping systems shall be pressure tested in accordance with the latest edition of the Code for Pressure Piping, ANSI B31.1, or twice the maximum working service pressure, whichever is more stringent. All leaks shall be repaired and the system recleaned and retested until leak-free.

Pipes must be adequately supported throughout their length and at all connections. Their locations must not interfere with the removal of other components. Pipe routing and support

shall be planned and accomplished in an efficient, organized manner to keep the total length and number of fittings and bends to an absolute minimum. Support and clearances provided between adjacent pipes and between pipes and surrounding structure, equipment or other appurtenances shall be sufficient to prevent chafing or contact due to any combination of car loading and deflection, vehicle dynamics, and thermally induced movement. In no case shall less than 0.125 inch clearance be provided. All unions shall be accessible.

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 vehicle 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 approved elastomeric or woven, non-asbestos, mineral fabric tape material to protect and sound insulate the pipe or tubing.

Wherever piping systems interface vibration-isolated rotating equipment, such as the refrigerant compressor, and rigidly supported carbody piping, approved flexible vibration isolating sections shall be used. Vibration insulators shall be installed parallel to the compressor crankshaft as close to the compressor as possible. The pipe connection at either end of the flexible elements shall be rigidly clamped not farther than 2 inches from the flexible elements. A metallic vibration isolator of an approved design shall be used for the refrigerant compressor.

All pipe clamps shall be inherently rigid and shall be firmly attached to the support point. Flimsy or excessively cantilevered clamps or clamp supports will not be accepted. Piping clamps and supports shall be attached to carbody or truck brackets; the use of other pipes or conduit as a sole support for a pipe clamp is prohibited.

14.2 Air System Piping

All Main Reservoir Pipe and Brake Pipe shall be ASTM A 53 Schedule 80 seamless pipe. Type "K" drawn ("H" temper) copper tube per ASTM B 88 may also be used, provided it is installed no lower than 2 inches below the floor panels and is protected from any potential impact damage from rail debris by means of equipment or approved steel guards, especially in the truck and outboard-of-bolster areas. Where suitable protection is not possible or practical, approved steel piping sections or approved rigid nonmetallic sleeves shall be provided in damage prone areas. The diameter of the Main Reservoir Pipe shall be 1 inch and the Brake Pipe shall be 1.25 inch.

All other carbody air pipes shall be sized in accordance with the function intended and may be ASTM A 53 Schedule 80 seamless pipe or copper tubing as described previously. Piping on the trucks shall be 0.5 inch minimum diameter ASTM A 53 Schedule 80 seamless pipe. Low spots (traps) are strictly prohibited on the trucks. Truck piping shall not be run on the bottom of truck side frames, transom, or bolster. There shall be only one hose connection from a truck to the carbody for each function (service/emergency braking, air suspension, etc.) with truck piping being used to interconnect all common systems.

All joints for copper tubing shall utilize fittings of wrought copper in accordance with ANSI Standards B16.22 and B16.88. Any part of the compressed air system on the vehicle using pipe threads shall use U.S. National Pipe Thread (NPT). Where carbon steel piping is used, all connections and joints where disassembly may be required shall utilize swivel type, socket or butt-welded flange fittings with an O-ring type seal. The use of threaded fittings is expressly prohibited, unless approved as a result of documented justification by the Vendor. Where changes in direction are accomplished by bending the pipe, the radius shall not be less than

specified by AAR Specification No. 2518, Standard S-400. Approved copper tube shall also comply with any relevant requirements of AAR Specification No. 2518 such as the prohibition of 90 degree elbows in the Brake Pipe, or low spots (traps) in any air piping. All air piping shall be installed in a manner to provide drainage away from devices, or branch pipe leading to devices whose function could be impaired by the accumulation of water or ice.

All air brake hose shall be wire reinforced air hose meeting the requirements of the Association of American Railroads Manual of Standards and Recommended Practices Specifications M-601 or M-618, using approved reusable fittings meeting AAR Specification M-927, with the exception of the brake pipe end hose which shall conform to AAR Specification M-601. Hose inside diameter shall be equal to or larger than the connecting pipe. Service ells and close nipples shall not be used. All cutout cocks (valves) shall be quarter turn type with locking handles painted yellow or white, except that the truck brake cutout cock handle shall be painted red. They shall be vented, except where function prohibits. Except for the Brake Pipe end valves, handles shall be arranged to be perpendicular to the pipe when open, and parallel to the pipe when closed.

All pneumatic system manifolds shall be constructed from rolled aluminum alloy plates using type 6061-T6 alloy in accordance with ANSI H35.1. Wrought aluminum tooling plates are prohibited. Petroleum-based machining coolants shall not be used in the manufacturing process. An anodized surface protection shall be applied prior to any bonding, and as a minimum shall meet the requirements of Military Specification MIL-A-8625 for Type II, Class 1. Requests for changes in these requirements must be submitted to the Engineer for approval.

14.3 Air Device Filters

Air filter assemblies with replaceable filter elements shall be provided in the air line that connects each subsystem to the air supply system. The filtering capability, flow rate capacity, and overall size shall be appropriate for the application so that the filter replacement interval shall be a minimum of once every 4 years. It shall be possible to gain access to the filter element for replacement purposes without requiring any pipe fittings to be opened. Filters shall be provided for each of the following systems, and any others operated from the air supply system:

a) each air brake control assembly
b) each leveling valve
c) any other pneumatic control device
d) cab car horn control valves.

14.4 HVAC System Piping

Air conditioning refrigerant lines shall be of annealed seamless copper tubing meeting the requirements of either ASTM B 280 or ASTM B 88 Type K. Sweat wrought type fittings meeting the requirements of ANSI Standard B16.22 shall be used. Joints shall be kept to a minimum and there shall be no inaccessible joints. Tubing shall be bent, wherever possible, to avoid the use of sweat fittings. Suction lines shall be designed and constructed without horizontal traps, and have a maximum 3 pounds/square inch pressure drop. The liquid line shall be sized adequately to prevent flashing due to pressure drop. Approved and surface sealed vibration isolators shall be used in piping connections to the refrigerant compressor. Tubing installations shall be designed such that any single length of tubing may be replaced without undue effort. All piping and pipe subassemblies shall be deburred after cutting, securely clamped in place,

thoroughly cleaned of all dirt and foreign matter, dried, and covered with tight fitting plastic caps or approved equal on all openings after fabrication. Caps shall remain in place until immediately prior to incorporation into the final assembly. After completion of final assembly, the system shall be cleared, evacuated and dried before charging. The system shall then be operated using liquid and suction filter dyers for a minimum of 30 minutes. After the run cycle is completed, the suction filter shall be removed, the suction screen shall be serviced, and the liquid line filter drier shall be replaced with a new element.

14.5 Water and Waste Piping

All water systems being supplied shall comply with the design requirements of Amtrak Specification 339. All water and waste systems shall have freeze protection systems provided in compliance with Amtrak Specification 531. Water and waste system piping shall be Type "K" drawn ("H" temper) seamless copper tube per ASTM B 88, or Engineer-approved non-metallic material. All joints for copper tubing shall utilize fittings of wrought copper in accordance with ANSI Standards B16.22 and B16.88. Piping shall be joined using silver solder. All piping shall be clamped with necessary sound insulation to prevent rattle, and must be sloped to allow drainage.

All waste piping lines shall be minimum 2 inch diameter seamless copper tubing without any sharp angles, and must have a constant downward slope toward the holding tank. All changes in pipe direction shall use a maximum of 45 degree "sweep" fittings. Wherever any piping enters from a branch, the piping must enter from above with a 45 degree wye. Cleanouts must be provided in areas where blockage might occur.

The water piping system shall be designed to permit gravity drainage of the entire car water system with an absolute minimum number of drain valves being necessary. Every low point in the car piping system shall be equipped with both an easily accessible manual drain valve and an automatic freeze protection drain valve and heater, in accordance with Amtrak specification 531, which shall discharge all the water in the car to the underside of the car. All drain valves must be located to provide both direct access for train crew manual drain valve activation, along with adequate maintenance access for servicing. The high points in the water system piping shall be equipped with automatic vacuum breakers as required to facilitate complete water piping drainage.

Complete freeze protection (heat trace tape and covering insulation) shall be installed for the entire length of the water and waste protection system, including water fill housings and waste system holding tank and drain pipes. Piping shall be installed so as to provide complete drainage to prevent damage by freezing.

14.6 Soldering

All copper tubing and associated fittings shall be joined using silver solder conforming to Federal Specification QQ-B-654A, Bag-5 or BCuP-5. Refrigeration and air brake system tubing shall be filled with dry nitrogen or approved equal non-oxidizing gas during joining. Condensate drain tubing may be joined using 95-5 solder or silver solder. Solder fittings shall be wiped and flux cleaned from tubing and fittings after soldering. Care shall be taken to avoid the introduction of flux into the piping system.

14.7 Pressure Vessels

All pressure vessels used on the vehicle shall conform to the latest revision of Section VIII of the American Society of Mechanical Engineers Boiler and Pressure Vessel Code for Unfired Pressure Vessels. Test reports shall be provided to the Engineer for each pressure vessel, and each pressure vessel shall be stamped or otherwise marked to document the test. The main air reservoir shall comply with the requirements of 49 CFR Part 229.31, including hydrostatic testing, and be drilled with telltale holes per paragraph (c). All pneumatic system reservoirs shall be drilled with telltale holes.

15.0 Coatings and Application

15.1 General

All paints and coatings shall be products which are commercially available in the United States in minimum 1 gallon containers, and which are approved by the Amtrak Chemical Committee. The vendor and its paint and powder coating suppliers shall supply touch-up paint and ensure that a continuing supply of touch-up paints and powders in colors used on the vehicle, suitable for spot application with a roller, brush, and sprayer, will continue to be available in the United States.

All steel including castings, except austenitic stainless steel, shall be painted, powder-coated or zinc-plated for corrosion protection. All weldments shall be cleaned in an approved manner to insure removal of all welding flux. Sand or grit blasting is preferred provided damage will not result to surrounding apparatus, and shall be cleaned following blasting. Immediately following inspection of the clean weldment to insure integrity of the weld, one coat of an approved primer shall be applied to prevent oxidation of the bare metal. All porous castings which could weep shall be sealed.

Prior to the application of any coating materials, all surfaces shall be completely free of grease, oil, welding flux, mill scale and other contaminants that would preclude proper adhesion. If required, surfaces shall be washed with an alkaline solution, properly rinsed, and then painted with a coat of wash (etch) primer prior to applying a primer in a manner recommended by the primer manufacturer. Surfaces specified to be painted, which will be concealed or inaccessible in the assembled vehicle, shall be prepared and painted prior to assembly.

All primers shall be completely compatible with any finish and/or intermediate coatings that are to be applied thereafter. Each layer of coating materials, whether primer, intermediate or finish coat, shall be free of runs, sags, or other application defects. All coatings shall be applied in a manner recommended by the specific manufacturer, spray application being used as much as possible.

15.2 Painting

All exterior steel surfaces and externally mounted equipment, except stainless steel or noncorrosive material, shall be primed and given a minimum of two finish coats of a polyurethane paint system, E.I. duPont de Nemours & Company, Inc. Imron or approved equal. Color shall be as recommended by the Amtrak Industrial Designer and approved by the Engineer.

Any parts of underfloor or roof equipment or enclosures made from plastic shall be painted in accordance with the above requirements, except the paint system shall be modified to suit the plastic used. Fiberglass with a colored gelcoat matching the specified color scheme shall not be painted. The inside surfaces of all underfloor or rooftop metallic equipment boxes, including all propulsion control and high voltage auxiliary electric equipment enclosures, shall be coated with an insulating, thermosetting, resin based, white powder coating, or a minimum of two coats of an approved nonconductive white paint, Glyptal, Inc. or approved equal.

Each truck shall have one coat of an approved primer applied on all exposed surfaces of the truck immediately after final cleaning, repairs and inspection. The truck shall be finish painted with two coats of black brittle truck paint, Yenkin-Majestic or approved equal, of a type that will not conceal any cracks that may develop in service, and allowed to air dry.

Any equipment, or parts of equipment, which would be damaged or suffer impaired operation from painting or powder coating shall not be painted and shall be corrosion resistant. The following items shall not be painted:

a) Aluminum or plated steel wire conduit and fittings
b) Elastomeric portions of piping
c) Wire and cable
d) Heat transfer surfaces and power resistors
e) Wheels and axles
f) Grease fittings
g) Mechanical coupler faces
h) Stainless steel piping and fittings
i) Stainless steel portions of the carbody
j) Stainless steel hardware
k) All elastomers
l) Signs, labels and nameplates
m) Threaded parts used for adjustments
n) Grounding pads and connections
o) Electrical insulators.

15.3 Powder Coatings

Powder coating materials are to be epoxy based or approved equal as recommended by the powder coating manufacturer for the specific application. The coating shall have a finished thickness between 1.5 and 2.5 mils, and shall have a finish hardness exceeding that of a number 2H pencil. The surface to be powder coated shall be prepared in accordance with the powder coating manufacturer's published recommendations. Powder coated parts which are scratched during handling and installation shall be touched up using a matching color epoxy paint that is allowed to cure prior to installation. Epoxy based powder coatings of middle to high gloss level shall have a minimum impact strength of 120 inch-pounds when tested in accordance with ASTM D 2794.

15.4 Corrosion Protection

The design of all components shall avoid the trapping and retention of water and debris. All surfaces shall be completely free of rust, scale, grease and other foreign matter immediately preceding the application of the primer. All joints shall be properly sealed with an approved waterproofing compound that will be compatible with the coatings applied. All surfaces that are

concealed after assembly shall be properly cleaned and coated with an approved preservative coating in a manner recommended by the coating manufacturer, especially inside surfaces of fabricated items. Where possible, dip coating of sections is preferred. Any arc welding performed on stainless steel shall be thoroughly cleaned and, if necessary, coated with an approved stainless steel coating material.

All aluminum surfaces, where required, shall be properly cleaned and shall be given a coating of an approved zinc chromate material. All joints between aluminum and other metals shall be suitably waterproofed and insulated with an approved compound which shall cover the entire area of each contact surface and conduct heat, if necessary. Aluminum heat transfer surfaces shall be anodized. If approved by the Engineer, heat transfer surfaces may be irridited to Military Specification MIL-C-5541E, Class 3, followed by priming and painting, provided that this treatment can demonstrate corrosion protection equivalent to anodizing.

15.5 Paint Process Documentation

The vendor shall prepare a paint coating and application document containing procedures and instructions for surface cleaning, preparation, priming, surfacing, and painting of all painted or powder coated equipment. A detailed paint schedule showing the equipment painted, paint type and manufacturer, recommended thickness, instructions for touch-up and any other pertinent information shall also be included. Material safety data sheets (MSDS) shall be provided for all products, including thinners and reducers. This document shall be submitted for Engineer review and shall be made part of (and cross referenced in) the maintenance manuals and parts list.

16.0 Electrical Design Standards

16.1 Design Criteria

Normal operation of an Amtrak passenger car DC electrical system, when the car is powered from the locomotive or wayside Head End Power (HEP) system, is 72 volts DC, plus 8 volts, minus 16 volts, with a ripple of less than 2 volts P-P (harmonics of 60 Hertz). Normal battery-only operation when the car is not powered from the HEP system is 64 volts, plus or minus 8 volts. There may be a momentary loss of power during the transition from HEP to battery, or battery to HEP operation.

Normal operation of an Amtrak passenger car AC electrical system, when the car is powered from the locomotive or wayside Head End Power (HEP) system, conforms to NEMA standards of plus or minus 10 percent of nominal voltage, and plus or minus 5 percent nominal 60 Hertz frequency. Standard AC voltages are 480, 240, 208/120, 120, and 28 volts. Refer to Amtrak Specification 429 for details.

All DC electrical system components shall function satisfactorily for any duration at any continuous voltage between 55 and 81 volts, when measured at the battery. They shall not be damaged or operate in an unsafe manner by the continuous application of voltages between 0 and 85 volts, and the application of 90 volts for 1 second. They shall also not be damaged or operate in an unsafe manner by the continuous application of battery voltages to carbody ground, by reverse polarity, or if any circuit inputs (including trainlines and trainline shields) are grounded or short-circuited. All AC electrical system components shall not be damaged from sustained undervoltage condition, or from reverse phase rotation. During normal operation of

the car, 480 volt AC power and all derived voltages (240, 208/120, 120 and 28) are often interrupted as follows:

Momentary (0 to 10 seconds typical), such as those caused by pantograph bounce on an Electric Locomotive.

Short Term (up to 1/2 hour typical), such as those experienced in locomotive changes or at adding cars to a train enroute.

Long Term (several hours to several days), such as those experienced in yard switching, train spotting and yard storage and service.

Due to the nature of Amtrak operations, cars are frequently added and removed from train consists and Head End Power (HEP) is removed. The vendor must coordinate the design of all circuits and equipment to prevent damage or disturbance to operation caused by electrical noise and transients. Whenever possible, this shall be done by suppression at the source. All circuits and equipment shall be designed and protected so that the sustained presence of any voltage from zero to the maximum will not cause damage to any part of the vehicle or cause unsafe operation. Reduced battery voltage is not expected during normal operation, but each vehicle component shall protect itself should such conditions occur.

All hardware shall be protected against moisture, oxidation, and common air-borne contaminants. Use of any locking compounds or anti-seize compounds on threaded electrical connections is prohibited. Conveniently located near any removable printed circuit board, or group of such boards, shall be a primary power switch whose opening shall make it possible to remove and replace such boards without injury to them. This switch may have multiple functions relating to troubleshooting and diagnostics as required. Equipment containing devices that are sensitive to electrostatic discharge (ESD) shall have provisions for hookups, properly identified, for attaching grounding devices. Equipment shall be designed to reduce or eliminate the need or requirement that maintenance crews be grounded during the maintenance of the cars. All circuits on the vehicle shall be designed to impose sufficient current load to positively eliminate any problems from "dry circuit" conditions to the satisfaction of the Engineer.

The need for adjustments shall be avoided wherever possible by the use of appropriate circuitry, stable components, and the use of high tolerance drift compensation and temperature compensation circuits. Where adjustments on printed circuit boards are necessary, they shall be accomplished without the use of specialized (i.e., non-catalog US supplier) test equipment unless this equipment is furnished by the vendor.

In general, all return circuits for any one system shall return to a single terminal point, without any connections to returns from other systems. Circuit design shall minimize both circuit complexity and number of components and shall annunciate component failures in a safe manner by responding or not responding, as appropriate, to commands for changes of state. Use of diodes shall be minimized and when used their failure shall not allow an unsafe condition to be created.

Electronic equipment shall utilize stock components and shall function properly with the component manufacturer's full range of tolerances such that after-purchase screening or testing of components shall not be required. Matching of components is permitted only if the components are normally available from the manufacturer in matched sets.

Equipment design consideration shall include separation of high voltage from low voltage devices. Components shall not be located near or above high voltage contactors. All low voltage components, controls, circuits and mounting hardware near or in the arc path of contactors shall be adequately protected against damage either by insulating material or by adequate distance.

All fiber optic cables shall be installed in accordance with the cable manufacturer's instructions, shall be adequately protected from damage of any kind, and shall be readily accessible for maintenance and inspection. Fiber optic terminations shall be designed to prevent degradation due to the vehicle environment, including vibration and variation in temperature, and shall be capable of inspection and repair without removal from the vehicle. Fiber optic cables shall be provided with a minimum of 10 percent spares on a location-to-location basis. Samples and technical details of all proposed fiber optic cables and connectors shall be presented to the Engineer for approval.

Capacitors shall be derated at least 20 percent for voltage based on the nominal supply voltage and maximum case temperature. Hermetically sealed metal-cased dry tantalum capacitors shall be used in place of aluminum electrolytic capacitors, except for very high values which are not commercially practical or available or where otherwise not appropriate, in which case long life grade aluminum electrolytic capacitors shall be used or in cases where tantalum is technically inappropriate. Alternates with equivalent service life may be approved on a case-by-case basis. Commutating capacitors shall be a paper or plastic film type and incorporate a nontoxic impregnant, and shall be chosen to give a service life of at least 20 years. Filter capacitors shall have high ripple rating for long life, and the sum of the DC and AC ripple voltage shall always be less than the capacitor's voltage rating at a maximum case temperature of 185 degrees F. All high voltage filter capacitors shall make use of bleeder resistors and/or other techniques to ensure their reduction to less than 50 volts within 1 minute in the absence of externally supplied power. The methodology details and expected results shall be submitted to the Engineer for approval. The resistors and their installation method shall be such as to ensure long life.

Except for accelerating and braking power resistors (unless determined to be necessary), all resistors shall be derated 50 percent for power dissipation. Transformers and inductors shall be derated at least 10 percent for current, or other appropriate approved factor, based upon the duty cycle.

Circuit design shall employ protective techniques such that failures in power semiconductors shall fail safe or fail open, and not cause consequent failure of components or major devices following them in the circuit. Except for the case of integrated circuits, or where environmental conditions make it a necessity, as exempted by the Engineer, no module employing multiple components shall be made nonrepairable by potting.

16.2 Semiconductor Standards

The vendor shall be responsible for insuring that all electrical and electronic circuitry, whether of its own design and manufacture or of those of its manufacturers and suppliers, shall meet, as a minimum, the criteria listed in this Section with regard to the use of semiconductors. Semiconductors for electronic circuits shall be adequate in current, power (both continuous and peak) and PIV rating and performance characteristics for the application intended. Semiconductors shall meet the following criteria and have the following minimum voltage

breakdown rating, depending on the use:

a) Semiconductors operated from the nominal battery supply shall have minimum breakdown ratings of four times the maximum circuit voltage. Suppression devices shall be provided as necessary to protect the devices and limit the circuit voltage. These shall be derated 50 percent for worst case transient dissipation.

b) Diodes operated from the nominal battery supply, used as suppression devices, shall have a minimum breakdown rating (PIV) of 1000 volts. Diodes with less than this rating may be used if adequate transient protection is also provided.

c) All discrete semiconductors operated from inverters or other isolating devices shall have minimum breakdown ratings of two times the maximum circuit voltage, except where specifically detailed otherwise. Suppression devices shall be provided as necessary to protect the devices and limit the circuit voltage. These shall be derated 50 percent for worst case transient dissipation.

All semiconductors, other than high power devices, shall be operated at less than 50 percent of the maximum continuous current rating, or 50 percent of the maximum continuous power rating, with the more restrictive rating being the controlling value. Circuits shall be designed to limit excessive current to semiconductors, to prevent damage from high discharges (spikes), and to limit excessive temperatures through properly designed heat sinks where required. Power semiconductors shall be applied with ample thermal margins which can be shown to be such as to ensure no less than 15 years of service life in the application and shall have overcurrent, overtemperature and overvoltage protection provided. Semiconductors shall be placed in a clean environment which shall favor easy replacement and ventilated as necessary. All power semiconductor circuits shall be passive air cooled. The electrical conducting surfaces shall be in dustproof, waterproof containers. Germanium semiconductors shall not be used. All semiconductor junction temperatures shall be limited to the maximum rated temperature for the device or 150 degrees C, whichever is lower, at maximum ambient temperature and rated output power.

Integrated circuits operated from the battery supply through inverters or other isolating devices shall be operated within the voltage and current ratings specified by the manufacturer, derated to less than 50 percent of the maximum stress level at the maximum operating temperature of the device as specified by the manufacturer. Where the supply to integrated circuits is regulated and surge protected, the voltage rating shall be 15 percent below the manufacturer's recommended maximum. In addition, the maximum power shall be limited to 50 percent of the manufacturer's specified maximum at the maximum operating temperature. Decoupling capacitors shall be distributed no less than one for every five integrated circuits.

All semiconductors shall be supplied in their hermetically sealed version and, other than microprocessors and other approved exceptions, shall be rated for operation over the temperature range of at least minus 40 degrees C to at least 85 degrees C. If a device is available from at least one supplier with a 125 degree C rating, then that version shall be used. Non-hermetically sealed packages will be considered, provided comparable reliability can be documented. All gallium arsenide and similar optical semiconductors shall be packaged in a manner suitable for the application and shall be rated for operation over the temperature range of at least minus 40 degrees C to at least 85 degrees C.

All semiconductors shall be Joint Electronic Device Engineering Council (JEDEC) registered

and numbered, and must be available from at least two different manufacturers which market them in the U.S. However, non-JEDEC registered devices may be used, provided that the vendor obtains prior approval based on submission of complete procurement specifications defining each such device and evidence of availability, based on those specifications, from two or more manufacturers which market them in the US. Semiconductor devices carrying greater than 100 amperes which are either non-registered, which have single sources or which have no domestic sources may be exempted from these registration and supply requirements as approved by the Engineer.

All plastic semiconductors shall be burned in and screened for defects to a level equivalent to MIL-STD-883, Method 5004, Reliability Class B, or approved equivalent. The method used must be submitted to the Engineer for approval. As a minimum, the supplier shall have had a proven effective component screening and burn-in program in effect for 5 or more years. Alternative methods based on a minimum 100 hour burn-in for the completed device which uses the semiconductors will be considered. The burn-in must be performed with the equipment operational (power on) and with the necessary input signals and loads to simulate the maximum power dissipating condition in the device at the maximum ambient temperature. Hermetic semiconductors shall receive screening and burn-in to procedures that can be documented to have produced assembled product reliability in accordance with the overall system requirements in this specification.

16.3 Printed Circuit Boards

Each circuit board shall be designed, constructed and inspected to the latest revision of MIL-STD-275 or approved equal, unless more stringent requirements are noted here. Traces shall be made as wide as practical, with the minimum width being based on a 10 degrees C temperature rise.

All printed circuit boards shall be of the "glass epoxy" type with the majority of the components mounted only on one side. The conducting copper laminate may be on both sides if required by component density or space constraints. In such cases, plated through holes shall meet the requirements of the Institute for Interconnecting and Packaging Electronic Circuits specification IPC-D-320 or approved equal. The copper foil laminate shall be firmly attached to the board, and be resistant to blistering and peeling when heated with a soldering iron. Run spacing shall conform with the latest revision of MIL-STD-275 or approved equal. The circuit board material shall comply as a minimum with the requirements of the latest revision of MIL-S-13949/4 type GF (NEMA Grade FR4) or approved equal with a minimum thickness of 0.0625 inch.

Each printed circuit board shall be identified by part or model number, in addition to serial number. The component side of the board shall be printed with the component references consistent with system schematics and such other information as may be required to repair and troubleshoot the board. Alternate methods of providing this information in a manner suitable for repair shop use may be submitted to the Engineer for approval. The component or wiring sides of the board shall be marked to indicate capacitor polarity and at least two leads of all transistors and thyristors. Diode polarity shall be indicated with an anode and cathode symbol. Integrated circuits and other multi-terminal devices shall have an index mark on the board, visible with the component inserted, to indicate proper keying and insertion; the number 1 pin on round packages and the first pin on dual in line packages shall be identified as well. All equipment shall be fastened to the board in such a manner as to withstand repeated exposure to the shock and vibration encountered in a rail vehicle environment. Sufficient clearance shall be provided between components to allow testing, removal and replacement without difficulty

due to lack of space. Large components shall be supported in addition to the solder connections. Power resistors shall be mounted in standoffs so that the resistor bodies do not contact, discolor or damage the board.

All EPROMS and programmable read-only memories (PROM's) that cannot be reprogrammed in-circuit and central processor units (CPU's) shall be mounted in sockets. In addition they shall be mechanically restrained such as by use of a ty-wrap. This requirement shall also apply to any integrated circuits with more than 28 pins per package which are not of the VLSI "gull wing" configuration, unless otherwise approved by the Engineer. The sockets shall comply with MIL-S-83502 and MIL-S-83734 or approved equal, as is applicable for the device. The bodies shall be molded from diallylphthalate, TFE Teflon or similar material as approved by the Engineer. The contacts shall be fabricated from beryllium copper, shall be plated with a minimum of 0.00003 inch of gold over a minimum of 0.00005 inch of low stress nickel in the area of contact with the integrated circuit pins and shall be of precision machined four-finger inner contact construction. Other service proven designs may be proposed for Engineer approval.

Both sides of an assembled printed circuit board shall be coated with an insulating and protecting coating which can easily be removed with a brush-applied solvent. The coating solvent shall not adversely affect board mounted components, and must be approved by the Engineer. The coating material shall be per MIL-I-46058 latest revision, or approved equal.

Provisions shall be made on all plug-in printed-circuit boards for "keying" to prevent insertion into the wrong socket. All wires, straps and functionally similar devices that are used to configure a standard circuit board for a specific circuit location shall be permanently affixed, or be located such that hand tools are needed to gain access, and the circuit board shall be keyed for the specific location. Spare multi-use circuit boards may be supplied unstrapped and unkeyed. The documentation shall provide full information for configuring and keying the circuit boards for each location in which they are used. All circuit boards in basic safety control systems such as doors, propulsion, braking or any other system which can cause unsafe operations if the vehicle is operated with a card removed shall be connected through a safety circuit to disable the system if a circuit board is removed.

Printed circuit board connectors shall be heavy duty, high reliability two-part type with successful service in railcar applications. The connector contact area shall be plated with a minimum of 0.00003 inch of gold over a minimum of 0.00005 inch of low stress nickel. Tin-plated contacts may be used if it can be shown that they are equivalent in long-term reliability. Connectors which comply with MIL-C-55302, latest revision, and which have plated contacts as described above, are considered to comply with the specification requirements. Wire wrap connections shall not be used except as approved in back-plane locations. Approval will be predicated on demonstration of prior performance in railcar applications. Ribbon (flat) cables and their connectors will only be allowed if a documented successful service history in railcar applications is demonstrated to the Engineer. Alternate materials may be proposed for specific applications for approval by the Engineer.

Test points shall be provided in appropriate locations on modules and printed circuit boards. A negative return test point shall be provided. The test points shall be a turret lug with sufficient clearance to permit it to accept a standard oscilloscope probe clip, and shall be identified by appropriate markings.

Printed circuit boards and modules shall be positively retained by means of keeper bars or other

approved means and printed circuit boards measuring greater than 7 inches on a side shall be equipped with side rails or reinforcing bars to minimize board flexing and to protect components during maintenance and handling of the circuit boards. Printed circuit boards shall not exceed 9 by 14 inches in linear dimension or 126 square inches in area. Each rack mounted printed circuit board shall be fitted with an ejector or hand grip to assist in board removal. The circuit board card rack and the edge of each board, or the card ejector, shall be labeled with corresponding numbers to identify circuit board location within the rack.

The vendor shall provide detailed maintenance and bench test troubleshooting procedures for each circuit board in the maintenance manuals, including wave forms and voltages at critical locations of the circuitry. Non-repairable or "throw-away' circuit boards may be supplied only by approval of the Engineer.

16.4 Interference and Transient Suppression

All electrical devices and wiring shall be carefully planned and selected to avoid electrical interference in the operation of the braking system, train radio, public address, cab signal and train control, cellular telephone, and any other frequency sensitive systems. This shall include the use of shielded cables, chokes, filters, and capacitors, as required by good design standards, to avoid possible interference with these systems. Adequate voltage transient suppression shall be provided for the protection of panels and circuitry involving semiconductor devices. Low voltage circuits shall be capable of withstanding 1.5 joules, unless otherwise approved by the Engineer.

Apparatus creating EMI emissions shall be designed to contain these emissions within their package area. Suppressors shall be incorporated across inductive devices to minimize switching transients. All suppression devices shall be selected on the basis of their ability to absorb the amount of energy available in the connected circuit, for the number of cycles of operation expected in service, without requiring replacement prior to scheduled overhaul. All magnet valves and relay/contactor coils shall have free-wheeling diode or metal-oxide varistor voltage spike suppression, or other suppression means, except where this results in deterioration of performance. Coil suppression devices shall be located physically on or as close as possible to the coil it protects (preferably directly at the coil terminal). Wherever possible, the suppression of transients shall be at the source.

17.0 Microprocessor Systems and Software

17.1 General

All computer hardware and software, whether resident within a microprocessor-controlled intelligent subsystem, provided as part of test or interface equipment, provided for the purpose of post-download data analysis and processing, or incorporated within training technology, is subject to the requirements provided in this Section. All hardware and software shall comply with the requirements of the Amtrak software safety plan in accordance with 49 CFR Part 238.105. Cab signal system apparatus shall comply with the requirements, unless otherwise approved by the Engineer, of IEEE standard 1483-2000, Standard for Verification of Vital Functions in Processor-Based Systems Used in Rail Transit Control.

Hardware and software requirements depend on the degree to which the hardware and/or software is custom designed for use by Amtrak. "Commercially available" computer systems or

software shall be readily available in the US through retail and wholesale sources and shall be subject to documentation and training requirements of this Section. "Non-commercially available" hardware, software and commercially available single circuit boards shall be subject to all of the design, documentation and training requirements of this Section.

Any computers, whether portable or not, (other than laptop and office-type personal computers) and any microprocessor hardware supplied to Amtrak shall be readily available through retail and/or wholesale outlets in the U.S. for 15 years, or a 15 year supply separately provided. They shall be from approved domestic manufacturers. If they are not available for 15 years, they shall be supported with replacement parts or be capable of being replaced with Form/Fit/Function compatible direct replacements, with replacement to be identified by the vendor. The vendor shall secure all necessary documents (including schematics, diagrams, interface requirements, printed circuit board artwork, firmware, custom component designs, software and documentation, etc.) to assemble the microprocessor-based hardware into an escrow account, so that Amtrak may have the hardware made by others in the event it becomes non-commercially available within 15 years. The hardware, software, data repository and firmware shall be able to process data (including, but not limited to, calculating, comparing, and sequencing) from, into, and between centuries, including leap year calculations. The date data processing shall not experience abnormal ending and/or invalid or incorrect results from the hardware, software, data repository or firmware in operation on Amtrak. Each hardware, software, data repository or firmware's date data interface shall support a four-digit year format. All of the date/time stamps used in all subsystems in the vehicle shall be synchronized to one source.

17.2 Microprocessor Standards

Microprocessor based control systems shall be based on an established family of microprocessors in wide use in the control system industry. They shall be supported by a full range of software development languages and diagnostic programs similar to that available for the Intel 80XXX family of devices. Should the vendor elect to use a multi-processor bus architecture, the architecture shall be based on the Intel Multibus, Motorola VME or similar bus used widely in industrial process control equipment. Alternative bus structures may be submitted for Engineer review.

Software upgrades shall be performed using a password protected function on a Portable Test Unit (PTU). Program code and fixed data shall be stored in PROMs or EPROMs. Either static or dynamic RAM or EEPROM may be used for temporary data storage. All EPROM windows shall be covered with labels that are opaque at the UV erasing wavelengths. Battery-backed RAM may be used only to store fault information. Batteries shall not require soldering, shall be sized to retain data for at least 6 months without charging, and shall be located such that leakage cannot damage any control system components. Battery life shall be no less than 5 years, regardless of type. All systems using standby or backup batteries shall annunciate the need for battery replacement such that the battery continues to perform its function until it can be replaced at the next vehicle periodic maintenance cycle. "Low battery" condition shall be provided to system and vehicle level diagnostic systems.

The hardware shall be designed to allow program expansion without hardware modification. The memory needs of the installed software shall not utilize more than 50 percent of the installed memory capacity. This requirement applies individually to each type of memory installed, whether EPROM, EEPROM, Flash PROM, RAM, or other type. Peak processing time demands shall not be greater than 75 percent (50 percent preferred) of the available processor

capacity. The hardware shall include spare input and output channels of each type used within the system, except for major output drivers where the quantity is fixed by the overall system design (e.g., destination sign character drivers). In addition, the architecture and assembly construction shall allow for the installation of additional I/O hardware.

17.3 Software

Software may be written in a high or low level language. The language, and its implementation for the selected microprocessor system, shall be commercially available in English. All software, whether interrupt based or polled, shall always assign the highest priority to safety related tasks. Software shall perform the following basic functions:

1) Implement the desired control scheme such that the specified performance is achieved;

2) Monitor all inputs for unsafe, erroneous, or unknown conditions or combinations of conditions;

3) Sample all input conditions in real time at rates sufficient to detect and remedy all unsafe or damaging conditions in the shortest possible time. Sampling rates and program execution times shall be such that the control system is not the limiting factor in response to unsafe or damaging conditions;

4) Limit all output commands to safe levels regardless of any combination of input conditions;

5) Perform self diagnostic routines and respond promptly, safely, and predictably to detected faults;

6) Respond safely and predictably when powering up or recovering from power interruptions. All power interruptions likely to have corrupted temporary storage shall be detected and cause the system to re-initialize all affected routines and temporary data. Detection of power interruptions may be performed by hardware.

7) Permit thorough interrogation of all input, output, and internal conditions by external diagnostic equipment. A software schematic diagram shall be supplied, where all variable names are shown as inputs and outputs to code sections, and the function of each section is explained.

8) Display the software revision level.

The vendor shall be responsible for any false information generated, transmitted, or processed in any subsystem, and shall provide a corrective resolution in a reasonable time period. Software version numbers shall be included within the firmware code and shall be accessible to the PTUs.

17.4 Isolation and Interfacing

The control system shall be powered by dedicated, transformer isolated, power supplies driven from the vehicle battery system. All control system input and output signals, including power supply voltages, shall be through isolation buffers. The buffers shall:

1) Protect and isolate the control system from damage due to overvoltage, undervoltage, transients, shorts, and opens.

2) Perform necessary voltage translations.

3) Remove noise and undesired signals.

4) Limit, pre-process, discriminate and format those signals that would otherwise require excessive processor time.

Signals which come from locations where there is proximity of 230 volt or above apparatus shall either be galvanically isolated or use another approved protection method that prevents logic damage if the signal is raised to the high voltage level.

17.5 Programming

Programming of microcomputers shall be divided into two classifications subject to Engineer review. The first classification shall be programs which are application independent and can be considered an inherent part of the controlled subsystem. The second classification, application dependent, shall include all programs which are specifically written for the operation and control of the vehicle.

The application independent programs shall include any safety related systems such as the friction brake controls, ATC, and other functions as reviewed by the Engineer. These programs shall be documented by the identification and description of all I/O functions, functional descriptions of the interfaces with all vehicle systems and subsystems, and all information required to ascertain the safe operation of the vehicle in response to any failure. The source code for these programs may be retained by the vendor, but full documentation must be supplied.

The application dependent programs shall include the vehicle logic, subsystem integration, and fault and diagnostic routines related to application dependent programs. These programs are usually tailored to meet the requirements of the application. The vendor shall recognize that Amtrak may at a future date have a need to change elements of these programs, and shall provide Amtrak with sufficient information to alter this vehicle software without the vendor's assistance.

The application dependent programs shall be programmed in a high level language such as C+ or PL/M. The language, and its implementation for the selected microprocessor system, shall be commercially available in English. All languages and operating systems must have an acceptable customer base (widespread use), and be approved by the Engineer. All operating systems, including those of PTUs and other test equipment, shall be able to communicate in a common language. The compiler used shall be commercially available. Proprietary compilers shall not be used. Compilation of the application dependent programs shall be performed on an IBM-compatible computer. The source code and all necessary files for the linking, locating, and conversion to hexadecimal object and/or executable binary code shall be supplied to the Engineer.

17.6 Documentation

For non-commercially available software, thorough and accurate software documentation, including source code, shall be submitted by the vendor for Engineer approval. Sufficient documentation shall be provided to permit the Engineer to fully comprehend and analyze the operation of the equipment in which the software is to be installed; and to enable Amtrak to maintain and modify the software to correct problems, adapt it to changing requirements, add features, and port it to a new hardware platform.

The vendor shall define a single software documentation methodology, subject to approval by the Engineer, and require all subcontractors to comply with it. If Computer Aided Software Engineering (CASE) tools are used which automatically generate documentation, they shall be consistent with the vendor's documentation methodology. The vendor shall provide descriptions to enable the Engineer to understand the documentation methodology. Software documentation training for specialized CASE tools shall be included within any training program.

Documentation for non-commercially available software shall be divided into two categories, subject to approval by the Engineer. Application-specific software (developed or adapted specifically for Amtrak, or newly-developed software that is intended for use on other applications as well) shall be fully documented in accordance with all requirements of this Specification. Application-independent software of an existing, service-proven design (fixed system software that is used in multiple applications (e.g., operating systems), or software that is encapsulated in a replaceable component (e.g., intelligent power modules)) may be exempt from certain Specification requirements, as approved by the Engineer.

17.7 Escrow Account

The placing of software design documentation details, such as proprietary source code or compilers, in a third-party escrow account, in lieu of submittal to Amtrak, may be permitted, subject to Engineer approval, provided that sufficient software information is provided (submitted and/or shown to an approved reviewer) to enable the Engineer to evaluate overall system performance. The vendor shall conduct a software escrow verification test for all escrowed software. These tests, at a minimum, shall verify that all software and developmental tools have been escrowed to compile, link, or otherwise generate the firmware, object code, P-Code, executable code, or whatever is required to run on the vehicle system or portable test equipment or other software-based system supplied by the vendor or its subcontractors.

The escrowed software design, documentation details, source code, etc., shall be made available to Amtrak for its own use if the vendor or its subsupplier is no longer in business, or no longer supports the product and has not transferred the rights to the design to another entity, or if, based on an independent third party assessment, the vendor or its subsupplier no longer supports the product at a reasonable cost. Amtrak shall be granted a no-cost license to use and maintain all software required to operate or maintain the supplied systems for its lifetime.

17.8 Non-Commercially Available Software

For non-commercially available software, the vendor shall submit for approval by the Engineer a Software Quality Assurance Plan (SQAP) in accordance with ANSI/IEEE Standard 730. The plan shall include the submittal and approval of the following documents:

a) System Functional Description,

b) Software Requirements Specification (SRS), in accordance with ANSI/IEEE Standard 830,

c) Software Design Description (SDD), in accordance with ANSI/IEEE Standard 1016,

d) Software Verification and Validation Plan (SVVP),

e) Software Verification and Validation Report (SVVR),

f) Software Configuration Management Plan (SCMP), and

g) User Documentation.

With the exception of the System Function Description, these documents are those required by ANSI/IEEE Standard 730. In addition, the final Software Design Description shall include details required by Air Transport Association of America (ATA) Specification number 102, "Specification for Computer Software Manual" through all levels to Level 6. The levels defined in ATA No. 102 are summarized below only for information:

Level 1: Computer description and operation,
Level 2: Software architecture, basic program and functions,
Level 3: Detailed flow information,
Level 4: Annotated compiler/assembly listing,
Level 5: Detailed memory map and listing, and
Level 6: Input/output port map.

After original approval, changes to the software shall be formally submitted for approval by the Engineer, prior to implementation. The software documentation shall be revised concurrently with software changes. All software shall be provided to Amtrak on CD-ROM.

17.9 Commercially-Available Software

Some software supplied under this Contract may be commercially available to a wide variety of users. Examples include operating systems supplied by chip manufacturers and data base software for wayside (off the vehicle) fault analysis. The vendor shall submit a list of software which is commercially available to the general public, subject to approval by the Engineer. For commercially-available software, software documentation requirements are limited to the original data storage/transfer media (CD-ROM), functional and usage details, all provider manuals, and all licenses required for Amtrak use for the life of the product. The vendor shall incorporate training on how the software is to be used in the specific situation for which it was provided, as part of any Training Program.

17.10 Configuration Control

The vendor shall develop a Configuration Control Plan for tracking software changes to delivered systems on Amtrak property until conclusion of the warranty. This plan shall be submitted for approval by the Engineer, and may be incorporated in the vendor's SCMP. It shall be consistent with the vendor's approach to configuration control of hardware and require similar approvals and tests. All software shall be identified by a name and a unique version number and date. The name shall identify the equipment into which the software is installed.

Every change to software shall be reflected in an update to the version number and date.

17.11 Software Maintenance

Amtrak retains the right to perform software modifications. All software shall be delivered to the Engineer on CD-ROM, except as specified above. The vendor shall provide a total of two software workstations, including the same version of all of the software and software development tools used by the suppliers. The complement of equipment shall include all compilers, assemblers, linkers, in-circuit emulators, and other such tools that are used for software development. All associated manuals shall be provided. The development system shall allow software modifications and tests of all rail application-related software related to onboard diagnostic equipment and all off-vehicle support equipment including, but not limited to, the PTU and DTE. The complete complement of software development/modification tools shall be delivered such that software modifications can, if desired, be made on-site during acceptance testing. Password protection shall be provided for modifications to all safety-critical software such as, for example, doors, ATC, and friction brakes. PROM reprogramming equipment shall allow reprogramming of PROMs at a rate adequate to support Amtrak maintenance needs.

The workstation and software documentation equipment is to be delivered, demonstrated, and proven to perform its function to the Engineer. The demonstration shall consist of Amtrak personnel using the workstation, source code files and written instructions to create program files that then must match the programs stored within the system's equipment.

17.12 Portable Test Unit (PTU) Software

For custom software that is resident in test computers, Amtrak shall be given a no-cost license for use and copying of the software for the approved purposes for the life of the supplied systems. Licenses shall not be linked to specific hardware serial numbers. In addition, complete portable interface equipment software documentation per above shall be furnished. The operating system employed for the PTU shall be the most-advanced, user-friendly system available at the time of design and development. While it is anticipated that the system shall be Microsoft Windows based, advances in technology may preclude this from being the best choice. Accordingly, identification of the system to be used will be made by the Engineer.

18.0 Electrical Devices

18.1 Contactors and Relays

All contactors and relays shall meet or exceed the requirements of MIL-R-6106 (for ratings of 10 amperes or greater) and MIL-R-5757 (for ratings of less than 10 amperes). Contactors 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. All high voltage contactors shall be suitable for 1000 volts AC service. All contactors and relays shall be utilized such that failures to respond shall be in a direction so that neither the passengers, the train crew, maintenance personnel nor the vehicle is placed in jeopardy. All devices shall be installed such that they are fully accessible for inspection, repair-in-place, or removal and replacement. There shall be a maximum of two wire terminations on any one contact of a device.

All coils shall be suppressed to protect against transients generated on the low voltage network. Under no circumstances shall main or auxiliary contact tips be placed in parallel for the purpose of carrying a current load at or above the manufacturer's tip rating. Installation shall be such that arc spray is directed by an arc chute away from ground and any other nearby electrical devices. The same applies to grounded mounting surfaces. Side doorway located relays, and any other relays subject to water splash, shall be environmentally sealed, except as otherwise approved by the Engineer.

Devices shall be constructed in a very heavy duty fashion suitable for use in rail vehicle service. Those which are in dusty areas or air streams shall be of an appropriately sealed type. Relays shall not be affected by the accumulation of airborne dust. All contactors shall be constructed such that the main tips make and break with a motion that prevents deposits and/or pitting. Blow-out coils shall be used as required. Contactor tips and arc chutes must be directly accessible for repairs with the contactor as installed in the vehicle and without the need to move other equipment. Contactors shall incorporate means of visually determining whether they are energized or de-energized.

The number of different relay types employed shall be minimized. Where practical, there shall be interchangeability of coil and contacts to minimize the number of spares needed. Bifurcated contacts shall be provided in low voltage applications whenever necessary due to dry circuit switching requirements, or low current switching, unless test data shows that it is not required. All time-delay relays shall be of the keyed R-C delay type for safety related applications, and of the electronic type for other applications. Mechanical or pneumatic time delay devices shall not be utilized. Solid state electronic timers shall be of proven quality with extensive, successful experience in rail vehicle service.

All relays shall be capable of at least one million electrical operations at rated contact capacity. Plug-in relays shall be keyed to prevent incorrect installation relative to voltage rating or function and be secured in their sockets by a mechanical restraint. This restraint shall be captive, of rugged construction, and easily positioned for relay installation and removal without the need for special tools. When the relay is removed, the restraint shall not 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. Plug-in relay bases shall allow for testing of each interlock by the use of a meter probe. Magnetic latch relays shall have integral reverse current protection, be insensitive to vibration and shock expected at the location and be oriented so as to minimize vibration and shock exposure. All relay sockets shall have clearly visible identification. Any location that has six or more relays in close proximity shall have a locator chart to aid in location. All devices shall be readily identifiable by means of a permanent, durable marking strip giving the device circuit designation. No identifications shall be obscured, or partially obscured, by wire routing.

18.2 Switches

All switches provided shall be of the highest quality procurable and shall be fully suitable for the rigors of a rail vehicle service environment. They generally shall be of 1,000,000 minimum cycle life unless otherwise approved. The design and selection of all switches shall be subject to review and approval by the Engineer. There shall be a maximum of two wires connected to any terminal of a device, and shall include sufficient wire slack to permit the replacement of an individual switch. Conductor door control switches, cab control switches, side doorway and

vestibule located switches, food service area switches, all exterior-mounted switches, and any other switches subject to water splash or spray shall be environmentally sealed, except as otherwise approved by the Engineer.

Switch contacts shall have a maximum resistance of 0.10 ohms at 3.0 volts DC with a 10 milliamp load when closed, and an open contact resistance of 50 megohms. They shall be rated for inductive loads, and have a contact material of silver, silver with a gold flash or gold plate, and be normally a break-before-make type. Switch terminals and connection points shall be silver or tin plated. All safety-critical switches, such as those that can cause door openings, shall be designed to withstand a high potential test of 1,500 volts for one second, in a clean dry condition, without false conduction. They shall have all exposed energized wire connections insulated in an approved manner to prevent false activation if bridged by foreign material.

Under no circumstances shall poles of switches be placed in parallel in order to carry currents equal to, or in excess of, the contact pole rating given by the manufacturer. Rotary switch orientation and function shall be such that handle movement from the normal position shall be clockwise, and normal shall be the 12 o'clock position. Non-rotary and non-pushbutton switches shall be mounted in a vertical position with the "up" position being On. No secondary mechanical means shall be utilized to achieve this. Switches shall be provided with a "keying" feature such that after installation, the body of the switch will be constrained from mechanical rotation. Switches shall be individually replaceable without disconnecting or removing anything other than the mounting fasteners and electrical connections of the switches to be replaced. Momentary contact pushbutton switches shall be limited to those having a positive indication of switch state. Pushbuttons which alternate between the on and off states with each successive actuation shall not be used.

18.3 Circuit Breakers

All circuit breakers shall be extremely rugged molded case devices with a frame size fully suitable for the service intended. They shall be the highest quality procurable, of trip-free design, dustproof, have moisture and fungus-resistant cases and components, and capable of withstanding the shock and vibration requirements of the rail vehicle service environment. Design and selection of all circuit breakers shall be subject to review and approval by the Engineer. Each circuit breaker shall have a tripped position (unless otherwise approved by the Engineer on an individual item basis) as well as an On and Off position, all being permanently marked on the handle or case of each circuit breaker and easily seen as installed.

A separate circuit breaker shall be provided for each branch circuit as well as for each major assembly and function. No circuit breaker shall protect more than one circuit, nor shall any one circuit be protected by more than one circuit breaker, except as specified otherwise. Circuit breaker terminals shall not be used as junction points. All circuit breakers shall be sized by current rating and tripping time to protect both the associated equipment and the minimum size wire used for power distribution within the protected circuit. Their performance shall not be affected by ambient temperature. Each pole shall be equipped with a trip mechanism consisting of an inverse time element for overload protection and an instantaneous magnetic element for short circuit protection. Circuit breaker poles may be connected in series if necessary to achieve the stated voltage interruption requirements. Each circuit breaker pole shall be equipped with adequate means of arc extinction 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 visible after installation. Electrically operated circuit breakers shall be arranged for operation from the low voltage DC supply. If circuit breakers are used to switch lighting loads, the circuit breaker shall be UL listed for "SWD" duty. Circuit breakers utilized in DC circuits shall be tested and rated for such applications.

18.4 Circuit Breaker Panels

Circuit breaker panels shall be of an approved safety "dead front" type, conforming to Article 384 of NFPA Specification 70 (National Electric Code). All live portions of the protected circuitry shall be completely concealed so that no danger of electrocution exists from the accidental touching of the panel or any appurtenances or devices mounted thereto. Circuit breakers shall be mounted in a vertical position with the "up" position being On. No secondary mechanical means shall be utilized to achieve this. Circuit breaker grouping or separation shall be based on operating voltage level.

Each panel shall be completely lined with a moisture proof, electrically insulating material such as fiberglass or approved equal. Asbestos shall not be used. There shall be provided a wiring gutter along the top, sides and bottom for the routing of wires to their designated circuit breakers. The panel cover shall be configured for easy removal so that maintenance and repair action is not impeded. All circuit breakers should be individually replaceable.

18.5 Fuses

The circuit protection function performed by fuses shall normally be performed by use of appropriately rated circuit breakers. Fuses shall only be used where specifically required by Amtrak or where use of circuit breakers is not technically feasible. All fuses used shall be standard catalog items commercially available from several US sources. All fuse holders shall be readily accessible and contain fuse retention devices at both ends. The type and rating of each fuse is to be clearly and permanently marked on both the fuse itself and adjacent to the fuseholder. Rejection lugs or other methods shall be used to prevent over fusing, if possible. Air gap and creepage distances shall be suitable for the application. Blown fuse indication shall be provided. All live portions of the protected circuitry shall be completely concealed so that no danger of electrocution exists from the accidental touching of any appurtenances or devices mounted thereto.

18.6 Bus Bars

Bus bars are to be fabricated from UNS number C10100 copper in accordance with ASTM B 187. UNS number C11000 copper may be used if not subject to welding or brazing due to its susceptibility to hydrogen embrittlement. Bus bar conductivity in the annealed condition shall be 100 percent as compared to the International Annealed Copper Standard (IACS). The bus bar temperature rise, including joints, shall not be greater than 30 degrees C above the enclosure ambient. Current density shall not exceed 1,000 amperes per square inch. Each joint shall be silver or tin plated, joined with a uniform 200 psi minimum contact pressure, and have a maximum current density of 150 amperes per square inch. Except for connection areas, bus bars shall be safety insulated using a high dielectric powder coating, heat shrink tubing or other Engineer approved means.

18.7 Inductors and Transformers

Inductors and reactors in power circuits, and transformers above 100 watts shall have copper windings with Class H solventless polyester synthetic resin vacuum-pressure impregnated or other approved insulation. They shall have minimum core losses and be of high efficiency design. Transformers and inductors shall be rated to withstand at least twice the maximum peak-to-peak voltage to which they are subjected in operation, and shall be derated a minimum of 10 percent for maximum current. All equipment and connecting cables shall be totally enclosed and shielded from flying ballast and debris, and from snow, rain, dust and dirt. Audible noise for power frequency devices shall not exceed 65 dB referred to 20 micropascals at a distance of 2 feet when operating at rated voltage and load.

18.8 Motors

All motors used on a vehicle, other than the refrigerant compressor, door operator, windshield wiper or other application approved by the Engineer, shall be a heavy duty, 4 pole, squirrel cage, continuous rated, 230 volts, 60 Hertz induction type motor, totally enclosed fan cooled except as otherwise stated, of an energy efficient premium design of service factor 1.15. Each motor shall be commercially available from at least two domestic US suppliers. Motors shall be 3 phase type unless otherwise indicated. They shall be constructed to allow long life and rebuildability. Each motor shall be rated for the highest ambient temperature encountered in its installed location, and shall be rated for a continuous duty cycle. Any motor weighing more than 25 pounds shall incorporate lifting provisions such as a lifting eye. All motors shall be rated and applied to operate from power supplied by on-board auxiliary power inverters. Rotating machinery shall be oversized, and suitable for continuous duty and frequent starts as will occur when an inverter is powered from a Head End Power system with multiple interruptions per hour.

Motors exposed to external weather, either directly or via an air stream, shall be weather and corrosion resistant and must have shaft seals and slingers. Motors used for blowers shall have their shaft length approved by the Engineer. The vendor shall document that the shaft length and blower type proposed have not experienced bearing or vibration problems in past applications due to dirt-caused imbalance.

Each motor unless otherwise required shall be designed, constructed and tested in accordance with the National Electrical Manufacturers Association Standard MG1-1978, Design B or Design C. They shall be suitable for full voltage starting, and be capable of accelerating to normal speed under load at 90 percent of rated voltage. The motor shall use permanently-lubricated and sealed ball or roller bearings designed in accordance with the Anti-Friction Bearing Manufacturers Association Standard 9 and Standard 11 as applicable for a L-10 life of 50,000 hours. Each motor shall be dynamically balanced, and shall not cause vibration in service. An arrow on the motor easily visible when installed shall indicate the correct rotation. Any motors exempted from the above requirements shall apply them to the greatest extent practical.

18.9 Sensors and Transducers

The design and installation of all sensors and transducers as installed in the vehicle shall not obstruct access to other devices in the vehicle, and their replacement shall not require the removal of other devices. The vendor shall verify that all devices are not subject to EMI/RFI conditions as used on the vehicle that exceed their design conditions or would cause them to produce erroneous data output. Specifications and calibration/test procedures for every device on the vehicle shall be included in the appropriate maintenance manuals.

19.0 Wire and Cable

19.1 General

Throughout this Section the term "wire" shall be interpreted to mean any insulated single conductor and the term "cable" shall be interpreted to mean any jacketed or bound together group of conductors except where otherwise described or defined within. The term "wiring" shall be interpreted to mean all wires and cables installed on the vehicle or its components.

All wire and cable used shall meet the requirements of Amtrak Specification 323. A minimum number of wire types and sizes shall be used in the vehicle. The 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 ICEA, ASTM, NEC, APTA, MIL or other approved equivalent specifications. Special attention shall be devoted to circuits where performance of the load is strongly affected by supply voltage, and wire sizing shall be carefully chosen to ensure that performance requirements are met. If metric based wire dimensions are used, they shall in all cases be equal or larger in diameter than the AWG equivalent and shall be replaceable with AWG based wire or cable without requiring modification to the vehicle or its components. Wire connections to motors shall be color coded by phase, and color coded (red/black) at the battery by polarity.

The minimum wire sizes used on all vehicle systems and subsystems shall be as follows, unless otherwise specified:

- number 14 AWG for wire which is pulled through conduits or wireways;

- number 22 AWG for wire on electronic units, cards and card racks;

- number 20 AWG for multiconductor cables where current is not a factor in wire size selection, such as for LED indicator lights or status displays; and

- number 14 AWG for all other wire, including wire which is laid in, rather than pulled through, wireways.

Exceptions must be submitted to the Engineer for approval.

Maximum wire ampacities unless otherwise specified shall conform to American Public Transportation Association recommended practice RP-E-009-98, Recommended Practice for Wire Used on Passenger Equipment.

All wire shall be surface printed with the manufacturer's identification, conductor size, voltage rating, and temperature rating. For wire sizes number 1/0 AWG and larger, stranding shall also be indicated as part of the wire marking. The wire marking shall be spaced at maximum intervals of 8 inches.

The use of ribbon cable shall be minimized. If used, ribbon cable shall be secured to prevent degradation to the cable and the terminations. Ribbon cables shall be used only for internal connections within an enclosure housing electrical assemblies that are replaceable. They shall not be used to connect electrical equipment housed in separate enclosures. Ribbon cables

shall be permanently identified with all circuit designations.

The vendor and any of its subsystem suppliers (through the vendor) shall send a sample and submit specifications of each size and type of wire and cable proposed for use for approval by the Engineer before proceeding with the work.

19.2 Conductors

Conductors in all electrical wires and cables, including wire and cables in apparatus furnished by subcontractors, shall be stranded soft annealed tinned copper in accordance with ASTM B 33. Stranding and conductor construction for all wires and cables shall be in accordance with the Association of American Railroads Manual of Standards and Recommended Practices, Recommended Practice RP-585, Wiring and Cable Specification, except that conductors required to flex when the vehicle is operating shall have stranding approximating the Insulated Cable Engineers Association, Inc. (ICEA) Standard S-19-81, Table L-7 (Class K) or Table L-8 (Class M) as appropriate. The use of solid wire is not permitted except for approved wire wrap applications.

19.3 Wire Insulation

Except as otherwise specified for special applications, all general vehicle wiring shall possess flame retardant radiation-irradiated crosslinked polyolefin insulation meeting the requirements of Underwriters Laboratories Specification 1581, Section 1080, VW-1 Flame Test. Insulation shall be of a minimum thickness consistent with voltage demands and may be of standard flexibility or extra flexibility configuration as appropriate for the application, with the requirement that number 6 AWG and larger wire must use extra flexibility insulation. Alternate material may be proposed on a case-by-case basis for specific applications. The insulation shall be rated at 2000 volts for wires carrying a nominal voltage greater than 200 volts, and rated at 600 volts for wires carrying a nominal voltage 200 volts or less. Insulation shall be capable of sustaining a continuous temperature state of 110 degrees C, but its operating temperature shall not exceed 90 degrees C. Insulation shall be in accordance with the Association of American Railroads Manual of Standards and Recommended Practices, Recommended Practice RP-585, Wiring and Cable Specification, and the following special requirements:

a) Flammability
Irradiated cross-linked polyolefin shall meet the requirements of test method ICEA S-66-524, Paragraph 6.12.5, except that after five flame applications of 15 seconds each with a three-second rest period between applications, the flame shall extinguish in ten seconds or less.

b) Smoke Density
National Institute of Standards and Technology smoke chamber test using a 5.0 feet long piece of number 12 AWG 2000 volt wire. Neither the maximum specific optical density (Dm) nor the specific optical density after 4 minutes (Ds-4 min.) shall exceed:

On a flaming test	200
On a non-flaming test	200

c) Capacitance Stability
Insulation shall meet the following requirements of test method ICEA S-19-81, Paragraph 6.9.2 at 90 degrees F.

Stability Factor	1.0 minimum
Alternate to stability factor; stability factor difference, 1-14 days maximum	0.5
SIC (1 day) maximum	6.0

d) Ozone
Using test method ICEA S-19-81, Paragraph 6.8, there shall be no insulation cracks after 24 hours exposure to an ozone concentration of 0.03 percent by volume at 90 degrees C, plus or minus 2 degrees C.

e) Tension Set
Insulation shall meet the requirements of test method ICEA S-66-524, Paragraph 6.4.11.4. As an alternative procedure, test method ICEA S-19-81, paragraph 6.4.13.4 may be used with the additional provision that the specimen shall be stretched until the gauge marks are 4 inches apart and that the average of three specimens not exceed a tension set of 30 percent.

f) Corrosivity
Using test method ASTM D 267, there shall be no more than 5 percent copper film removal after a test period of 16 hours at 175 degrees C, plus or minus 2 degrees C.

g) Moisture Absorption
Gravimetric method at 70 degrees C plus or minus 20 degrees C for 168 hours.

Mg per square inch	8 maximum

Electrical method ICEA S-66-524, increase in capacitance, percent

1-14 days	3.0 maximum
7-14 days	1.5 maximum

19.4 Special Applications

Special circuit integrity wire to be used in communication circuits and other selected locations shall possess an insulation of polyolefin jacketed silicone rubber capable of sustaining a continuous temperature of 125 degrees C.

All wires for high-temperature applications, such as those connecting to heaters and resistors, shall be abrasion resistant Teflon (polytetrafluoroethylene) TFE as compounded by E. I. duPont de Nemours and Company, Inc. meeting MIL-W-22759/6B. In addition, for wire sizes number AWG 18 and smaller, Kapton film insulated/liquid H aromatic polyamide per MIL-W-81381/22 (AS) may be used. When used for interconnecting pieces of apparatus, the wire must be in bundles with a protective covering.

All wires within replaceable modular units and electronic apparatus, such as cards and card racks, shall be insulated with either Kapton per MIL-W-81381/22 (AS), radiation crosslinked polyolefin, or TFE (polytetrafluorethylene) Teflon Types EE per MIL-W-16878/5 or E (for number

12 AWG or smaller sizes) per MIL-W-22759/6/8.

Wire used for connections to the Operator's console, and in other location where there is minimum space available or equally crowded concentrations of low voltage wiring, may be insulated with Kapton per MIL-W-81381/22 (AS).

19.5 Multiconductor Cables

Multiconductor cables shall be constructed using wires as described above. All multiconductor cables shall have at least 10 percent spare conductors by design. Where required to obtain a circular cable cross section, fillers shall be made of non-hygroscopic materials compatible with the wire insulation and jacket and be of the same or of a higher temperature rating than the wire insulation. A binder tape shall be employed over the assembly of conductors in multi-conductor cables if needed to assist in cable manufacture, or if required to permit the cable to function as needed for its application. The binder tape material shall be non-hygroscopic and shall be of the same or higher temperature class as the wire insulation and shall be of a compatible material.

Shields for use in cables, if required, shall consist of either copper braid or aluminum/polyester tape with a drain wire, as is appropriate for the application. Copper shields shall be made of either tinned 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 95 percent. Shield strand size and application shall be as recommended by the cable manufacturer for the particular application. 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 percent of the tape width to ensure complete coverage. In contact with the aluminum side of the shielding tape shall be a number 22 AWG 7/30 tinned copper drain wire conforming to ASTM B 33 and B 174.

The overall jacket of multiconductor cables shall be of radiation crosslinked modified polyolefin or TFE Teflon to match the wire insulation and application. It shall be extruded and vulcanized over the cabled conductors, and shall be well centered, with a smooth appearance without objectionable roughness or irregularities, consistent with good industry practice. Cables used to connect the end of vehicle trainlines shall be specially constructed for the constant flexure of this service and shall have prior service that has been satisfactory. This shall be verified by documentation to the satisfaction of the Engineer.

For high temperature applications, multi-conductor cable shall conform to MIL-C-27072, latest revision, with type V conductors, style 4 sheaths, class D jackets (if needed), and shields (if needed).

19.6 Wire Wrap

The use of wire wrap connections shall be avoided. Wire wrap connections may be used only in selected electronic applications as approved by the Engineer on a case-by-case basis. In all such cases, the conductor shall be number 28 AWG soft or annealed oxygen-free solid copper, with a silver conductor coating having a minimum thickness of 40 micro-inches. Wire shall have "MIL-ENE" insulation or approved equal, and shall be manufactured to MIL-W-81822/1A. The insulation shall have a minimum 300 volt rating, and a temperature rating of 135 degrees C.

Wrapping shall be "modified" wrap, nominal 7.5 turns, including 1.5 turns for strain relief.

20.0 Wiring

20.1 Application and Installation

All wiring shall be performed by qualified, experienced wiring personnel using appropriate tools for stripping insulation, cutting, soldering, and attaching mechanical crimp type terminals with the correct dies and tools as provided by the terminal manufacturer. Proper stripping tools shall be used when removing insulation from any conductor. All wire cutting tools must be sharp, must be adjusted to avoid nicking, cutting, or otherwise damaging the conductor strands, and no more insulation than is necessary should be removed. Damage to wires shall not exceed the following limits:

Wire Size (AWG)	Allowable Strand Damage
14 or smaller	2 nicked, none broken
10 or 12	4 nicked, none broken
8 or larger	6 nicked, 6 broken.

Vehicle wiring shall be in conformance with American Public Transportation Association recommended practice RP-E-002-98, Recommended Practice for Wiring of Passenger Equipment, except where otherwise specified. Parallel connection of conductors to achieve required ampacity is not permitted except under special circumstances as approved by the Engineer.

Unless otherwise specified, all wires and cables shall be enclosed in raceways or conduit, having sufficient junction boxes and pull boxes to permit easy replacement of wires and cables. Wherever removable apparatus, components and equipment are provided, a quick disconnect shall be provided.

Insofar as practicable, all wiring shall be fabricated into convenient units ("harnesses") on a bench and installed in standardized locations. Each branch of each circuit shall be easily separable from others for troubleshooting. Conductors which operate at potentials differing by 50 volts or more shall not be cabled together and shall not be placed in the same conduit, junction box, or enclosure. Each area of a raceway, duct, junction box or enclosure divided into two or more distinct areas by metallic partitions may be considered separately in the application of this rule. Where it is impossible to avoid having wires differing by more than 50 volts in the same equipment enclosure, the wires shall be physically separated and bundled separately. All wiring connected to a piece of apparatus shall be insulated for the highest voltage connected.

Wiring connected to possible transient-generating apparatus shall not be run adjacent to wiring carrying signals to, from, or between semiconductor, logic, cab signal or communications circuits. In cases in which adequate physical separation is impossible, shielded wire of an approved design shall be used for all conductors involved. All wires connected to a circuit breaker or any other protective apparatus shall be able to cause that apparatus to operate and remove power without suffering thermal damage to the wire. A drip loop shall be provided in each wire or cable where water could otherwise run along the wire or cable to the point where it

enters a box or enclosure.

All wire and cable, including that in ducts and conduit, shall be handled to be free of kinks and insulation abrasions. Wire installation shall not be subject to accumulation of water, oil or other foreign matter. All wire and cable shall be protected by grommet material at ends of wire ducts and at other locations where cables enter the ducts. All wire and cable shall be fully protected against any contact with any surface other than that designed specifically to support or protect the wire. Protective edging and similar material shall be applied wherever any possibility exists for a wire to contact a sharp edge for any reason.

Fiber optic cables shall be provided with a minimum of 10 percent spares on a point-to-point basis. Wires from different conduits or other openings shall not be harnessed together with wires running within the box. Each harness or group of wires between equipment enclosures shall contain a minimum of 10 percent spares, but no fewer than two spares for each wire size. All spare wires shall be individually identified.

Wire and cable dress shall allow sufficient slack for removal and reapplication of the wire terminations at least twice (three times on 10 AWG and smaller wire), as well as permit the replacement of switches and contactors, without excess tension. Wire splices will not be permitted, except with the expressed approval of the Engineer.

Wire and cable ties shall be snug but shall not be so tight as to cause indentation and cold flow damage to the insulation. Adhesive installed mounting bases shall not be used for ties or cable support.

The layout of wiring shall be designed in advance of its installation and in cooperation with those furnishing the related equipment. No wire or cable shall be located within 6 inches of the side of the vehicle as measured at the side sill, whether in open run or contained within conduit duct or wireway. All circuits and branches shall be separable by means of terminal boards to isolate portions when troubleshooting. All circuits requiring as part of regular maintenance a high potential test shall be so arranged that they can be conveniently set up for the tests.

All wire bundles and cables within an enclosure shall be supported by the use of tape rails and shall be free from the enclosure structure, metal edges, bolt heads and other interference points, and shall have electrical clearance from the covers regardless of the insulation properties of the covers. Wire bundles shall be located above or alongside the apparatus rather than at the bottom of the enclosure wherever possible. In all cases, wire shall be a minimum of 1 inch above the bottom of the box. Wire entry into control or junction boxes shall not be permitted through the bottom of the box. Wires shall avoid exposure to contactor arcs. All similar equipment boxes shall have identical wire routing, location and termination.

Wiring needed to calibrate or test any vehicle function shall be a part of the permanent vehicle wiring in order to enable Amtrak to maintain the equipment. This wiring shall be properly identified and terminate in connectors in the respective control groups and cabinets.

Wire shall be protected from damage during all phases of equipment manufacture. All wire, including that in ducts and conduit, shall be handled to be free of kinks and insulation abrasions and shall not be exposed to accumulation of water, oil, or other foreign matter. The ends of the wire shall not be permitted to lay on wet floors or other damp areas where moisture may be absorbed into the conductors. Wire shall not be walked on, dragged across sharp edges or abrasive objects, twisted or otherwise mishandled.

Pulling compound, if used, shall be non-conductive, non-hygroscopic, non-odorous, and shall not attract vermin. Solder shall be ASTM B 32, Grade 60B. A non-corrosive flux shall be applied immediately before soldering. An automatic temperature controlled solder pot shall be used.

Usage of electrical tape shall be subject to the approval of the Engineer, and in all cases shall be minimized. Electrical tape shall be polyvinyl chloride as specified by the Association of American Railroads Manual of Standards and Recommended Practices Standard S-540, Section F, and in addition shall be Underwriters Laboratories listed and a minimum of 0.007 inch thick.

20.2 Cable Connectors

In general, the use of cable connectors shall be minimized. With the exception of specific specialized applications approved by the Engineer, all cable connectors shall be of the same style, of the environmental watertight variety with removable crimp contacts of the correct size for the wire being terminated. Connectors proposed for such specialized applications must meet the quality and life cycle criteria given below.

Cable connectors shall be equipped with sealing gaskets on the front, so that the connector interface is sealed, and on the back where the cable enters. A grommet shall be provided in the backshell to cover the interface of the wires to the connector pins to prevent shorts between adjacent circuits. Extension bodies shall be used if necessary to insure that there is sufficient room to both terminate the cable wires and have the cable jacket extend within the body, be held by a clamp, and have a gasket seal the entrance. Unused connector pin positions shall be sealed with either connector contacts or plastic sealing plugs designed for that purpose. Adjacent connectors shall either use different inserts or different insert orientations (keying) to prevent erroneous connections.

All cable connectors shall conform with MIL-C-5015, and be a positive locking, quarter turn bayonet coupling with metal shields, waterproof seals and crimp style gold or silver plated contacts. The coupling mechanism shall be spring loaded with stainless steel locking pins at the peak of the receptacle bayonet ramp to provide extended coupling life of a minimum of 2000 operations. Audible, visual and tactile indications of full coupling shall be given, and lockwires shall not be required. Where necessary, EMI shielding shall be provided. All connectors shall be Litton-Veam CIR series or approved equal heavy duty electrical connectors, as approved by the Engineer.

20.3 Undercar Wiring

All undercar wiring shall be run in closed wire ducts or conduits in an approved manner and shall be securely clamped via a compression-type rubber sleeve in watertight strain relief bushings with insulated throat lines at entrance and exit points. Wire and cable shall be secured in the ducts to prevent chafing movement. The wire ducts and conduits shall be of drip-proof construction unless exposed to car wash spray due to their location. In such cases they must be watertight and of non-corrosive material.

Any enclosure containing wires (such as conduits and wireways) shall be sized such that the sum of the cross-sectional areas of the wires (including conductors, insulation, jacketing, etc.) does not exceed 40 percent of the inside cross sectional area at any point. In the case of

wireways and ducts the actual lay of wires shall not go more than 90 percent of the way to the top of the vertical walls. Bends in the ducts shall be avoided; however, if they are required, protection as approved by the Engineer shall be provided to avoid insulation chafing at the bends. Cables shall be laid in place with sufficient slack at the bends so that cables will clear the inside bend surface of the duct, thereby preventing crushing of insulation.

All electrical connectors used on the vehicle exterior shall be totally environment-proof. All jumpers, jumper heads, and jumper receptacles shall be sealed in an approved manner to prevent the entry of water at any operating speed of the vehicle.

20.4 Cleating of Cables

Insulated wire and cables of adequate physical strength (number 1/0 AWG or larger) may be cleated in place at intervals of no more than 1.5 feet in place of use of conduit or raceways. All cable and wiring exiting raceways or cable which is not installed in conduit shall be cleated using split block cleats of molded neoprene rubber. The neoprene shall be a nonflammable, insulating type with a durometer value of 50 to 60. Each cleat shall have a stiffener of at least 10 gauge corrosion resistant metal 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 of approved design. Each lead in the cleat shall have its own cutout sized to the correct wire diameter, without use of tape. The cleat shall permit replacement wire in American Wire Gauge (AWG) to replace any metric-dimensioned wire originally installed. Cleat spacing shall be sufficient to prevent excessive wire sag. A minimum number of cleat block types shall be used.

Use of loop-type supports may be proposed to the Engineer for use on an individual case-by-case basis provided that the clamp material is stainless steel, the cushion material is either ozone-resistant neoprene or silicone, and a chart is provided to identify the proper size clamp for use with each size cable and for each mounting location. This size information must also be identified in all parts listings. A minimum number of different size clamps shall be used. The use of tape or other methods on cables to enable them to fit in an oversized clamp of any type is prohibited.

20.5 Installation of Wire in Conduit

Conduit shall be sized such that the sum of the wire cross-sectional areas (including conductors, insulation, jacketing, etc.) does not exceed 40 percent of the inner cross sectional area of the conduit for three or more conductors. For two conductors a limit of 31 percent shall be used while for a single conductor a limit of 53 percent shall be permitted. Where conduits having a length not exceeding 2 feet and without bends of more than 15 degrees are used between enclosures, a maximum fill of 60 percent shall be permitted.

A run of conduit between junction boxes and/or pulling outlets shall not contain more than the equivalent of four quarter bends (360 degrees total) including the outlet fittings. Bend radii at the inner edge of the bend shall be no less than eight times the nominal inside diameter of the conduit. Where a conduit extends for longer than 15 feet, it shall have a "tee" fitting with drain plug at the midpoint.

20.6 Terminals and Wire Terminations

The method used for wire terminations such as terminals, terminals blocks and connections shall be the mechanical solderless type, made by an approved domestic U.S. manufacturer with

a comprehensive line of available components and application tools. Several types of terminal systems are acceptable to the Engineer as specified herein, but it is Amtrak's intention that the vendor select one of these systems, which shall then be the only system used throughout the vehicle or to the greatest extent possible. The vendor may propose use of terminal blocks of either the screw clamp or spring clamp type, or use mechanically-crimped ring-type terminals along with stud or screw type barrier strips. All "Faston" type terminations used on the vehicle shall be composed of either beryllium copper or phosphor bronze. There shall be a maximum of two wires connected to each terminal of any piece of electrical equipment or device, except where noted elsewhere. The proposed terminal system, along with complete technical details, shall be submitted to the Engineer for approval. Wherever a screw touches a wire conductor directly without a clamp bar, the wire conductor must be ferruled.

Terminal blocks shall be of the molded unit type and shall comply with the requirements of UL 1059, "Standard for Terminal Blocks." The terminal block shall be either of the screw-clamp type which compresses the wire between two surfaces without the clamping screw being in direct contact with the wire, or of the WAGO Cage Clamp or approved equal type, where an clamping spring mechanically secures the wire against a contact. Regardless of type, all metal parts shall be held captive in the molding of the terminal block and live parts shall be recessed so as to prevent their being touched. Terminals shall be of dead front design or furnished with protective covers. Assemblies of individual terminal blocks shall be of the unit form suitable for mounting collectively on a standard mounting rail to give the required number of connection points. Each single unit must be spring retained in the mounting rail and shall be close-fitted to avoid the accumulation of foreign matter between adjacent units, and with the capability of replacing single blocks without removing adjacent terminal blocks. The open side of the last terminal of an assembly shall be closed by an end barrier. Different sizes of terminal blocks in an assembly may be fitted in a sequence as required. Both ends of the assembly shall be supported by an end bracket. Screw retention for any component from the rear of the mounting rail is not acceptable. Terminal blocks shall be of a size permitting wire sizes as required. The size of the terminal block may be determined by the spacing requirements of UL 1059, Table 7.1. Each individual terminal shall be identified by a secure terminal marker bearing identification as indicated on the circuit diagram. Terminal blocks shall have an approved snap-in terminal identification method capable of at least two digits on two alpha characters which are molded in. Identifications shall not dislodge or fall out due to normal maintenance and assembly activities. Terminal blocks with isolating devices shall be of a design which gives a positive indication of an open circuit. Terminal blocks shall be marked permanently with the manufacturer's name or trademark, the maximum voltage rating and the maximum current rating or maximum wire size.

The terminal block molding shall be either a polyamide or Nylon material which will not support combustion and shall be self-extinguishing according to UL Standard 94. The comparative tracking index of the molding must be at least 500. The molding shall be non-hygroscopic. For screw clamps, the clamping yoke and clamping screws shall be made from a high-grade heat-treated alloy steel, protected against corrosion by zinc or cadmium plating and dichromated, and be so designed as to furnish positive locking action when the screw is tightened. For spring clamps, the clamping spring shall be made from high quality austenitic chrome nickel steel, with contact surfaces of tin coated electrolytic copper. The internal current carrying parts of all terminals shall be made from copper or copper alloys and shall be tin/lead electroplated. Mounting rail retaining springs shall be made from non-corrosive materials such as stainless steel. All accessories to the terminal blocks shall be made from similar materials as the terminal block itself. WAGO Cage Clamp connectors shall be limited to those on the 264, 280 and 281 block series with previous successful rail vehicle applications.

Only a single conductor shall be applied to each terminal connection. Terminals shall be attached to the wiring with the proper crimping tools and dies recommended by the manufacturer. Where possible, the terminal used shall be of the type which securely grips and holds the insulation. Wires connected to screw clamp terminal blocks shall be ferruled as recommended by the subsystem manufacturer, but as a minimum shall be applied to wires smaller than number 14 AWG. Conductors which may be subjected to motion relative to the terminal shall be protected by suitable means to prevent breakage of the conductor at or near the terminal. A minimum of 10 percent spare terminals shall be provided on each terminal assembly with at least one spare terminal being provided if there are nine or less active terminals. Number 6 and smaller screw-type terminal boards shall only be permitted with the approval of the Engineer. Terminal boards in accordance with MIL-T-55164A matching the voltage range of the circuits involved may be proposed where physical conditions favor the use of such and where redesign of equipment would be otherwise required.

Where mechanically-crimped wire terminals are used, they shall be high quality devices as supplied by AMP, Thomas & Betts, or approved equal. Terminals shall be ring lugs equal to Military Standard MS-25036. Use of spade and hook-type terminals are prohibited. Terminals shall be attached to the wire with the proper crimping tools and dies as recommended by the terminal manufacturer. The Vendor shall minimize the total number of crimping tool types needed for crimp connections. All crimping tools shall be of the ratcheting type that lock at each advance until a full crimp is achieved, only at which point they will release. Where possible, the terminal used for number 10 AWG wire and smaller shall be of the type whose barrel securely grips and holds the insulation. Conductors which will be subject to motion relative to the terminal shall be protected by suitable means to prevent breakage of the conductor at or near the terminal. Terminals fitting wire sizes number 10 through 22 AWG shall require no more than three tool models to provide certified crimp connections. The vendor shall submit the proposed product line for approval, including documentation that each series of proposed terminals have been tested to a level equal to Military Specification MIL-T-16366F for temperature rise, voltage drop, vibration, current overload, and corrosion. When a mechanically-crimped wire termination is applied to a solid wire lead on an electronic component, such as a diode or MOV, the termination crimp shall also be soldered to prevent long-term vibration effects. Wherever several wires are connected to terminals of a terminal strip on a device which is removable from the vehicle for maintenance, the wires shall be terminated, with separate ring terminations which shall be screwed to an insulating fanning strip that shall serve to keep the terminations in the correct relative locations while removed from the device, unless otherwise approved by the Engineer. A maximum of one wire shall be crimped to any one terminal.

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 terminal changes. Cable conductors shall be cleaned prior to installation of terminals. 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.

All barrier strip terminals shall have brass studs or zinc chromate plated steel, and connections shall be locked using double nuts, single nut with brass flat washer and plated spring-type lock washer, barrel nuts, or approved elastic stop nuts. Barrier strip terminals shall be of dead front construction with no exposed energized parts, or be provided with removable covers. Studs and washers may also be made of corrosion resistant steel. Each barrier strip shall have at least 10 percent spare terminals, with a minimum of one. Binding head screw type terminal boards will

be permitted only where approved. All barrier strip terminals shall be in accordance with Military Specification MIL-T-55164A or equivalent standard. Brass studs must be capable of withstanding the force applied to elastic stop nuts when removing or replacing nuts. Threaded studs shall have a minimum of 2.5 threads exposed beyond the final nut. Adequate space shall be provided to permit connecting wire terminals with standard tools. All terminals shall be properly torqued to assure sound connections. Spacers shall not be used. Jumpers between barrier strip terminals shall be brass, plated steel, tin-lead electroplated copper, or zinc chromate plated steel. Wire jumpers are not permitted. An approved permanent marking strip shall be provided and attached at each barrier strip terminal adjacent to each wire. A maximum of two wire 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 between terminal barrels. The wiring shall be arranged so that no more than two terminals are connected to a stud, from each side of the terminal board. The use of adhesive-mounted terminal board identification labels is prohibited.

Any bolted lug style cable connections shall be of the two-bolt type, with crimped or soldered tube-type lugs. The termination shall be covered by either a Neoprene (chloroprene) traction motor connector type sleeve, or by an approved Raychem RW 3031 series LNCL roll-on sealing sleeve of cross-linked, thermally stabilized, modified EPDM rubber, or approved equal. Wire connections shall be color coded per phase as well as identified.

20.7 Ground Connections

All grounding and bonding jumpers and straps shall be installed with sufficient slack to prevent any damage while in service. Where required, they shall be sized to handle fault current, for which the voltage drop shall not exceed 25 volts. 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 connections to the carbody shall be made through copper or bronze pads of adequate area, silver soldered or brazed to a steel plate which is welded to the carbody structure.

The vendor shall insure that all possible conditions of ground-loop current are eliminated between trainline shields, any communications port of vehicle microprocessors, and the PTUs. All equipment enclosures and shock-mounted equipment shall be safety grounded with flexible insulated copper grounding wires, with insulation rated for 2000 volts and green or green/yellow in color. All grounding connections shall have special attention given for strain relief and vibration protection.

20.8 Conduit

All conduits and fittings shall be galvanized steel, with a minimum size of 0.5 inch. Rigid steel conduit shall be mild steel in standard lengths with threaded ends and hot-dipped zinc-coated exterior and interior surfaces. It shall be free of burrs and projections, circular in cross section, of uniform wall thickness, and shall conform to the requirements of ANSI C80.1. Threads shall conform to ANSI B2.1. All conduit fittings shall be steel which shall be treated, coated, and threaded according to the requirements for zinc-coated rigid steel conduit, and shall conform to UL 6. The open ends of conduit shall be provided with strain relief-type fittings with extended rubber cushions, bell-mouth fittings, or insulated throat box connections as approved.

When sheared or sawed, all conduit ends shall be deburred inside and out to remove sharp edges and all pieces blown out with compressed air to remove all filings before installation.

Conduit shall be securely clamped and metallic conduit shall be electrically grounded. All conduits shall be arranged to prevent moisture traps and shall drain toward control boxes. All clamps shall be inherently rigid and shall be firmly attached to the support point. Flimsy or excessively cantilevered clamps or clamp supports will not be accepted. Conduit clamps and supports shall be attached to carbody or truck brackets; the use of other pipes or conduit as a sole support for a conduit clamp is prohibited. The conduit arrangement and installation shall be subject to approval by the Engineer.

Aluminum conduit and flexible non-metallic nylon conduit which meets the requirements of Section 2 may be proposed to the Engineer for approval for carbody interior locations on a case-by-case basis. Use of flexible conduit for enclosure connections may be submitted to the Engineer for approval on a case-by-case basis. Flexible conduit (Sealtite) shall be used only where absolutely required and shall be subject to Engineer approval. Flexible covering on conduit shall not contain polyurethane or PVC.

20.9 Fittings and Junction Boxes

All fittings and junction boxes for vehicle wiring shall be metal as manufactured by the vendor or by a supplier of a comprehensive line of fittings and boxes. The vendor shall submit the proposed product line to the Engineer for approval. All junction boxes located on the vehicle end sheets, used for trainline jumper receptacles, and for end of vehicle trainline terminal strips shall be stainless steel. All other undercar or exterior junction boxes shall be fabricated of hot-dipped zinc-coated steel with a minimum wall thickness of 14 gauge. All covers shall be provided with gaskets using approved materials, and shall be retained with captive screws. Covers shall be completely removable. Screws and other hardware shall be zinc plated or stainless steel. All undercar or exterior junction boxes shall be weatherproof and gasketed, shall have provisions for breathing, 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 protected with a white insulating paint or other approved process. Drain holes shall be equipped with stainless steel cotter keys with the ends turned up, or similar system as approved by the Engineer. All junction boxes, including pull boxes, are to be orientated so as to be directly accessible for maintenance.

20.10 Splices

Splicing of conductors shall be avoided and will be permitted only with the expressed approval of the Engineer on a per-item basis. Under no circumstances will splicing of conductors in conduit be permitted. In the event a splice is approved, it shall be in a junction box and the spliced joint shall be both as mechanically strong and as conductive as any other part of the conductor. The splice shall be an insulated permanent crimp splice in accordance with Military Specification MIL-T-7928G, Type II, Class 1, and shall be installed with the crimping tool and die of the splice manufacturer. All splices shall be insulated with a self-sealing, weathertight, seamless shrink tubing. The outside diameter of the spliced portion of the cable after the insulation is applied shall not exceed the outside diameter of the unspliced portion by more than 40 percent. Splices shall be identified in the integrated schematic.

20.11 Marking

White or yellow permanent type identification marker sleeves with black printing shall be used to plainly and suitably identify all wires (including spares), regardless of location, and all terminal blocks or strips, subject to the approval of the Engineer, so that circuits may be easily identified.

The technique used shall produce clear, legible identification markers that are highly abrasion resistant and immune to dirt, grease and oils. Marking materials and inks shall not be adversely affected by normal electrical cleaners and solvents. Hand printing is prohibited. The wire markers shall be double printed 180 degrees apart, to permit reading the marker despite rotation about the wire. The use of adhesive on the inside of the sleeve is prohibited. The sleeving shall be UV protected to withstand exposure to the elements without discoloration. The marker sleeves shall be sufficient robust to prevent any damage or dislocation during wire installation, including pulling wires through conduit and grommets.

Each circuit shall be individually designated, and each wire shall be individually designated from point to point. All wire smaller than number 6 AWG which is external to equipment enclosures shall have its circuit identification number or other nomenclature stamped on it at 12 inch intervals. Wiring connected to polarity-sensitive devices within any enclosure or assembly must be identified sufficiently to permit the device to be removed and be properly installed. All battery box wire identification markers shall also clearly identify the positive and negative connections, as well as provide red and black color codings. Wires attached to terminals shall also have a marker indicating both the terminal board and the individual terminal to which it is attached. Whether connected to male or female side, all wires connected to quick disconnects shall have identification markers affixed, shall be color coded, or shall have their identity stamped on them at 3 inch intervals over the last 12 inches of the wire using the same methods as required above.

A wire designation system shall be submitted for approval which will coordinate all electrical circuits in the vehicle in a unified systems approach. Individual designations shall be provided for all spare wires. There shall be no common designation for return circuits in either power or control circuits. All male and female quick disconnects shall carry approved identification and shall be keyed wherever the design used offers this possibility so that improper connections cannot be made. In locations with six or more disconnects, a locator chart shall be provided to aid in location and reconnection.

20.12 Insulation Resistance

All carbody wiring and cables shall be designed, constructed and installed so as to be capable of having a minimum insulation resistance as detailed below, prior to its connection to underfloor equipment and other components.

The minimum acceptable resistance to a solidly grounded carbody for each class of vehicle wiring shall be as stated below, when tested at the listed voltages using an approved megohm meter. All wiring is assumed to be solidly grounded except the wire class under test:

Wire Class	Voltage	Minimum Result
600 volts	1000 volts	50 megohms
480 volts	1000 volts	25 megohms
230 volts	1000 volts	25 megohms

37.5 volts or below	500 volts	5 megohms

All carbody wiring and cables shall be capable of withstanding a high potential test with a minimum duration of 60 seconds, using an applied 60 Hertz voltage as listed below. The application and removal of the voltage shall not exceed a rate of 150 volts/second. During the test period, the current leakage shall not increase. All wiring is assumed to be solidly grounded along with the carbody except for the wire class under test:

Wire Class	Test Voltage
600 volts	2200 volts
480 volts	1400 volts
230 volts	1400 volts
37.5 volts and below	500 volts

Inasmuch as the insulation resistance varies with the season and humidity, the vendor shall insure that these requirements can be met under the most severe climate conditions.

20.13 Wireways

All wireways, raceways, cable trays or cable ducts (referred to as "wireways" hereafter) may be used in underfloor locations, or in the car interior ceiling area or electrical lockers. Wireways in underfloor locations shall be constructed of either uncoated stainless steel, or rigid carbon steel with a permanent low smoke elastomer coating to minimize the risk of oxidation and rust formation. Wireways used in the car interior shall be constructed of either corrosion-protected carbon steel or aluminum, stainless steel or polycarbonate. Proposed wireway locations shall be submitted to the Engineer for approval.

All wireways shall be adequately supported throughout their entire length in a manner approved by the Engineer. There shall be absolutely no sharp edges, and all trays shall be completely deburred before installation on the vehicles. Grommet clamps shall be provided at all locations where cables or wires enter the wireways. Under no circumstances shall leads be dropped over the edge of the wireways, with or without wireway edge protection. In underfloor locations, covers shall have sufficient engagement to prevent the entry of car washer chemicals. Wireway elbows, couplings and similar fittings as well as all internal fastener heads shall be flush with the interior surface. Fasteners shall not be directed toward the interior of wireways. All metallic wireways shall be grounded.

All wireways shall be routed such that they avoid sources of heat, wheel splash areas, and areas along the vehicle where the trays may be subject to foreign object damage. The wireways shall be located such that it will be possible to reach the harnesses contained within for maintenance activity. Wireways may be perforated, without jeopardizing their strength, to permit ventilation and drainage, but shall prevent the accumulation of leaves. All wire and cable shall be securely fastened within wireways to eliminate movement and resultant chafing.

Wireways shall not contain more than 30 wires at any cross-section. The sum of the cross

section areas of all contained wires, including conductors, insulation and jackets, shall not exceed 50 percent of the interior cross sectional area of the wireway.

20.14 Wire Tying Devices

Wire tying devices shall be of approved ozone and ultraviolet resistant material and shall adequately retain the wires for the life of the wiring. Those used within enclosures shall be designed for enhanced ozone resistance. Where possible, the wiring shall be prefabricated into standard harnesses, wrapped and tied with a high strength tie designed not to invade the wire insulation, and include spare wires within unit compartments. Generally, wires shall be installed and marked with the same arrangement and location with all identifications visible in each vehicle having similar apparatus. Spare wires shall be so marked on each end. Wire tying devices shall be mechanically fastened to permanent structure. Adhesives are not permitted.

20.15 Circuit Shielding

The design of all circuit shields shall be carefully arranged to avoid the creation of ground loop currents. Wire and cable shields, where used, shall be continuous up to the vehicle's electrical trainline jumpers. The wire shields shall be connected through all applicable connectors and junction boxes. Coaxial cables used as constant impedance transmission lines shall be terminated as dictated 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 vendor shall carefully categorize each circuit. Shields contained in one circuit category shall not be interconnected with shields contained in another category. Shields used to protect against interference shall not carry signal current. 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 trainline jumpers) 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. Loops due to interconnections of shields shall not be permitted.

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 and shall be double shielded. The resistance between these circuits shall be at least 500 megohms when 500 volts DC is applied.

21.0 Lubricants

The vendor shall attempt to the greatest extent possible to make use of lubricants in the maintenance of the vehicles which are in current use at Amtrak. All lubricants proposed for use shall be approved by the Engineer. The vendor shall inform the Engineer of a minimum of two domestic U.S. suppliers of such lubricants, available in containers of 5 gallons or less. High-performance, low life-cycle cost synthetic lubricants may be proposed for use.

The vendor shall supply a listing in the relevant repair manuals of each type of lubricant required, which shall include a specification reference to Federal or Military Specifications, the American Petroleum Institute or Society of Automotive Engineers Standards, and a minimum of two domestic U.S. products identified by trade name.