Massachusetts Bay Transportation Authority

Red and Orange Line
New Vehicle Procurement

TECHNICAL PROVISIONS

October 22, 2013

TECHNICAL PROVISIONS

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* Not included in the technical specification at this time.

PART T 01.00
GENERAL

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1.01: OPTIONS

1.01.01. Car Builder Proposals

A. Car builders are requested to include technical details and separate cost quotations for each item listed as OPTION in this specification. The Authority may elect to incorporate none, any or all options, at their sole discretion.

B. If the Authority does not select a particular option, provisions (e.g. circuit breakers, cables, conduit, antenna mounts, etc.) to add this option at a later date and outside of this contract's scope shall be provided as much as feasible. Details shall be discussed during the preliminary design review.

C. Quotations shall include impact to schedule, if applicable.

D. List of Options:

1. CCTV Display Screen (T 05.03.11)
2. Gap Mitigation Device / Bridging Mechanism (T 06.02.10)
3. Internal and External Passenger Door Open Buttons (T 06.03.03)
4. LCD Displays (T 13.02.15)
5. Active Map Display (T 13.02.16)
6. Automatic Passenger Counting System (APC) (T 13.02.22)
7. Training Simulator (T 22.02.08)

1.01.02. Authority Notification

A. The Authority will notify the car builder of any options elected on or before Notice To Proceed (NTP).

B. Options elected by the Authority will be incorporated on all vehicles ordered under this contract.

1.02: GENERAL

A. This specification details the requirements for the Massachusetts Bay Transportation Authority's (MBTA) procurement of Rapid Transit Vehicles for use in Boston and the surrounding metropolitan area. The specification has been written to define the requirements of the MBTA's Orange and Red Line vehicles.

B. Not used.

C. The specification is largely performance based. This approach has been selected to reduce design time and vehicle costs by allowing Contractors to make use of existing designs. Detailed design requirements have been minimized, but performance testing to prove compliance with the specification is stressed.

1.03: ORANGE AND RED LINE VEHICLES

A. The vehicles to be procured under this specification have been designated the #14 Orange Line cars and the #4 Red Line cars.

B. Married Pair numbering will be sequential. The numbering scheme will be provided during preliminary design review.

C. The Orange and Red Line vehicles shall be designed to operate at 80,000 miles per year with a minimum service life of at least 30 years.

D. not used.

E. The two vehicle types shall be produced concurrently, but with the Orange Line vehicles starting the delivery sequence. Further details are provided in the Terms & Conditions.

F. The existing #12 Orange Line vehicles are scheduled to be retired upon completion of the procurement, while the new Red Line cars will operate in service with the existing #2 and #3 Red Line cars. Mechanical coupling shall be required for pushing and towing on both the Orange and Red Lines. Electrical coupler/trainline compatibility is not a requirement between new and existing vehicles on either line.

G. The specification calls for as much commonality between the two vehicles as possible, considering that the size and weight of the vehicles will differ. Where feasible, vehicle sub-systems and components shall be identical in design, with software adjustments being utilized to tailor equipment performance to each line.

H. All requirements included in the specification apply to both the Orange and Red Line vehicles unless stipulated otherwise.

I. Deliverables such as documentation, training and special tools shall be provided separately for each vehicle type unless stated otherwise in the specification.

1.04: VEHICLE DESIGN

1.04.01. Vehicle Configuration

A. The vehicles shall be arranged in a semi-permanently coupled Married Pair configuration. Each Married Pair shall consist of a Cab Car and a Non-Cab Car.

B. Married Pairs shall have the capability of operation in both directions. The Non-Cab Car shall be fitted with a hostler panel in the No. 1 end to allow limited operation from that end of the Pair.

C. Not used.

D. Not used.

E. The vehicles shall meet or exceed all current applicable requirements of the Americans with Disabilities Act (ADA).

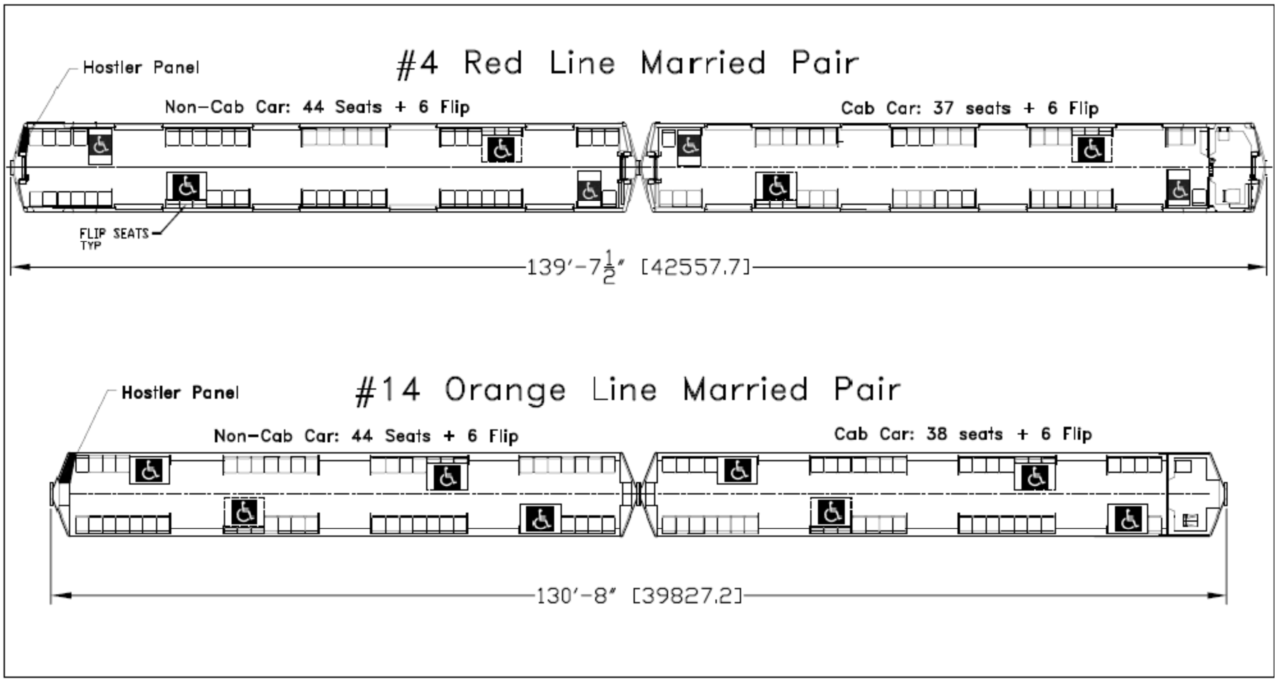


Figure 1-1 - Red and Orange Line cars - Vehicle Configuration

1.04.02. Right of Way/Operating Environment

A. The Orange and Red Line vehicles operate on dedicated tracks in surface, elevated and subway environments. The Orange Line has 11 miles of service track in each direction operating between Oak Grove and Forest Hills. The Red Line has 21 total miles of service track in each direction. The Red Line runs from Alewife to JFK then splits to two lines, terminating at Ashmont or Braintree.

B. The Orange Line vehicles are maintained at the Wellington Maintenance Facility located in Medford. The facility consists of a carhouse and storage yard. The carhouse includes pitted tracks, flat tracks, car hoists, wheel house, wheel cutting machine, paint booth and a wash track. 600 volt shop power is provided by an overhead trolley system. Orange Line cars are also stored at the Forest Hills Yard.

C. The Red Line vehicles are maintained at the Cabot Maintenance Facility located in South Boston. The facility consists of a carhouse and storage yard. The carhouse includes pitted tracks, flat tracks, car hoists, wheel house, wheel cutting machine, paint booth and a wash track. 600 volt shop power is provided by and overhead trolley system. Red Line trains are also stored at Alewife Yard, Cadigan Yard (located at Braintree Station) and Codman Yard (located at Ashmont Station). Personnel perform minor tasks at Cadigan and Codman Yards.

D. The entire right of way of both the Orange and Red Lines is fed from a nominal 600 volt dc third rail.

1.04.03. Weight Limit

A. As a result of infrastructure limitations, the vehicles delivered under this specification have absolute weight limits. The maximum weight for the Orange line vehicle is 110,000lbs, and for the Red Line vehicle is 125,000lbs. Vehicles that exceed these maximum allowable weight limits will not be accepted.

B. The Contractor shall be required to provide a detailed monthly weight report to ensure adherence to these limits. Refer to T 02, Vehicle Design Requirements, and C 8.03B for detailed requirements.

1.04.04. Fasteners

A. Fasteners used in the design of the vehicles shall be SI (metric). Inch-standard fasteners shall not be used, except as approved by the Authority on a case by case basis.

B. See T 18, Materials & Workmanship, for detailed requirements.

1.04.05. Specification Conflicts

A. Any conflicts or ambiguities within this specification shall be brought to the attention of the Authority for clarification.

B. This specification has been developed primarily in customary US units of measure. SI conversion units are listed in parenthesis. If a conflict occurs in a conversion, it should be assumed that the English measure is accurate.

1.05: RENDERINGS

1.05.01. General Requirements

A. The Contractor shall utilize the services of an experienced Industrial Design firm to supplement interior and exterior vehicle design efforts to achieve a modern and aesthetic appearance while maximizing functionality, operator ergonomics, and maintainability.

B. The Contractor shall submit renderings that convey the modern looks and aesthetic properties of the new Orange and Red Line vehicles. The renderings shall be fully realistic, including color, texture and light reflection, and shall include a minimum of 6 exterior, 6 interior and 6 cab views of each vehicle, with details described below, taken from different viewpoints.

C. Renderings shall be provided in electronic format as well as 2 dozen sets of high quality D size (24 in x 36 in) poster board backed prints for display in public reviews. [CDRL 01-01]

1.05.02. Exterior Renderings

A. The Contractor shall submit exterior renderings of the complete carbody, including end masks, doors, windows and all exterior features, for approval by the Authority.

B. Renderings shall be fully detailed and include all visible exterior equipment.

1.05.03. Interior Renderings

A. Interior renderings shall be provided to convey options for interior layouts, color schemes and passenger amenities. Cabs may be included in the interior renderings or produced separately.

B. Seating arrangement and hostler panel layout in the front end of the Non-Cab Car shall be prominently depicted in the renderings.

1.06: SCALE MODELS

1.06.01. General Requirements

A. The contractor shall provide 6 scale models of the Orange Line Married Pairs and 6 scale models of the Red Line Married Pairs. Models shall be based on approved exterior arrangements. Models shall be 1:30 scale, fabricated from wood or equivalent material and painted to match the selected artist rendering. Scale models shall be provided with a polycarbonate display case and shall be delivered to the Authority no more than 12 months after Notice to Proceed (NTP). [CDRL 01-02]

1.07: MOCK-UPS

1.07.01. General Requirements

A. Separate mock-ups shall be provided for the Orange Line and for the Red Line.

B. Mock-ups shall be employed for use in conveying the proposed design as it progresses through the stages of review. The mock-ups listed below may be combined into a single unit for the Orange Line and a single unit for the Red Line.

C. Mock-ups will be used by the Authority for public display.

D. As the design of the vehicles progress, the mock-ups shall be continually updated until the final design review is accepted and assembly of the pilot cars begins.

E. Mock-ups will become the property of the Authority. Mock-ups for each vehicle type shall be shipped by the Contractor to Boston to separate locations determined by the Authority at a later date.

F. Components listed as 'operational' shall be powered and function identically to production components on the completed vehicles.

G. Section C5.06 details further requirements for mock-up submission.

1.07.02. Virtual Mock-Ups

A. The Contractor shall utilize electronic mock-ups from the conceptual stages of the project through final design review. Three dimensional modeling shall assist the

Contractor and Authority in coming to agreement on the general design direction. [CDRL 01-03]

1.07.03. No. 1 End Mock-Up

A. The No. 1 end mock-up shall largely be focused on Operator comfort, ergonomics, control reach and visibility. Glare and reflection mitigation shall be evaluated. Screen and display visibility in direct sunlight shall be demonstrated. [CDRL 01-04]

B. Mock-up components shall include the following, at a minimum:

Front End Mock-Up
Cab wall, including windows, curtains and amenities mounted on the wall
Cab door, including lock/latch, hold open device, etc
Sidewall liners, end wall liners and ceiling panels, complete with air vents speakers, overhead lights, etc
End door, including latches, seals, window, and hold open device
Sliding cab Side windows
Windshield, showing actual field of view for operator
Sun visor
Operator's Seat
Cab heater/side window defroster
Cab Console
All Cab control devices, including bypass switches, console buttons, circuit breakers, master controller panel and door controls, bridging device controls (OPTION)
Duplex gauges, communications control panel, automatic announcements control panel (AACP), handset, gooseneck microphone, push to talk microphones and radio
VMS screen, CCTV display, ADU display, and all other components included in the cab that may be washed out by direct sunlight
Enclosures for equipment, including access panels and interior component layout
All safety and emergency equipment locations (evacuation chair, ladder, stretcher, two fire extinguishers)
Operational Instructor's seat and Operator's foot rest
All cab lighting - operational
Exterior Components - Front End Mock-Up
Front end mask
All exterior lights - operational

Front End Mock-Up
Operational Front Destination sign
Horns
End Gates/Barriers
Windshield wiper/washer system
Loop steps/grab bars

1.07.04. Passenger area Mock-Up

A. The mock-up shall extend from the cab wall, past the second set of side doors and terminate with the No.1 end wall of the Non-Cab Car. The mock-up shall provide sufficient length to house all equipment lockers in the No.1end of the Non-Cab Car, as well as the hostler panel and all controls/access panels. [CDRL 01-05]

B. Exterior components, including anti-graffiti coating and signs, shall be included in the mock-up.

C. The accessible provisions and amenities will be of particular importance to the Authority. The entrance platform shall be adjustable to simulate the Authority's worst case gaps and ensure that the gap mitigation device performs satisfactorily.

D. Mock-up components shall include the following, at a minimum:

Passenger Area Mock-Up
Passenger Seats, including cantilever support
Typical application of all stanchions and hand rails used throughout the car
Wide and narrow versions of windscreens
Floor panel and lining, including Low Level Exit Path Marking (LLEPM)
Sidewall and ceiling lining, interior speaker
Operational Light fixtures, air diffusers
Passenger doors, including thresholds, and Operable Gap Mitigation Device (bridgeplate) (OPTION)
Side windows
All door pushbuttons, indicator lights
Baseboard heater at required watt density, heater guard and sidewall insulation
Accessible area including hand rails, Passenger Emergency Intercom (PEI)
Passenger Emergency Stop with End Door Release

Passenger Area Mock-Up
Over door LCD Displays and operational Active Line Map (OPTION)
Operational, transverse LED passenger information signs
Operational side destination signs
Advertising card holder on door pocket liner
Advertising card holder on corner hatch
Non-Cab Car Components - Passenger Area Mock-Up
Non-Cab Car equipment arrangement including enclosures
Non-Cab Car hostler panel
Access covers for all controls and maintained equipment
Bicycle Racks
Hostler end door
End wall windows
Exterior Components - Passenger Area Mock-Up
All exterior indicator lighting - operational
Anti-graffiti coating, passivated brush finish, decals, signs
Door open pushbuttons
Exterior speakers
Exterior door release

1.07.05. Underframe Mock-Up

A. A virtual underframe mock-up shall be provided. [CDRL 01-06]

B. The virtual underframe mock-up will be used to ensure compliance with the specification. Of particular importance will be verification of requisite clearance, accessibility and maintainability requirements. All pneumatic and electrical equipment including piping and wire runs and conduit shall be included.

C. Verification of access clearance to all equipment enclosures shall be provided.

D. The virtual mock-up shall be complete. All underframe mounted components shall be modeled and included.

1.08: DEFINITIONS, ACRONYMS & ABBREVIATIONS

1.08.01. Definitions

A. The table below lists definitions of technical terms used throughout the specification. The list is not intended to be all inclusive.

Item	**Definition**
-A-	
Acceptance Test:	Test performed on a car using production items to determine whether or not the item complies with specified requirements for the purpose of confirming that production items are at least equal to the qualified item.
Accepted:	Found suitable to the Authority, subject to successful completion of all testing.
Accident:	An accident is an unplanned event which results in injury or death to passengers or personnel and/or damage to or loss of equipment or property.
Adhesion, Coefficient of:	At the instant of transition between rolling and sliding contact, the ratio between the longitudinal tangential force and the normal force at the wheel-rail interface.
Adverse Grade:	A condition in which the inclination of the track is in a direction to oppose desired acceleration or braking, that is, downhill for braking and uphill for acceleration.
Alignment, Horizontal:	The horizontal location of a track as described by curves and tangents.
Allowable Stress:	Stress level permitted in a structure under specified design conditions.
Anticlimber:	Fingers at the ends of cars that are designed to engage adjacent cars (when the units are subjected to large buff loads) to prevent climbing and subsequent telescoping of one car into another.
Approved:	Confirmed for use on the contract by the Authority. Approval does not relieve the Contractor from meeting all requirements of the specification.
Automatic Coupler:	A coupler which when mechanically engaged also engages electrical and pneumatic trainlines between cars.
Automatic Speed Regulation (ASR):	The subsystem within automatic train control which performs the functions of speed control.
Automatic Train Protection (ATP):	System which receives and decodes speed command signals transmitted by wayside equipment and prevents the train from exceeding the commanded speed.
Auxiliary Systems:	Any mechanism or structure other than the Transit Vehicle body, traction, or propulsion system which performs a function at some time during the operation of the Transit Vehicle, such as heating and air conditioning system, door operation system, motor alternator, air compressor and lighting.
Auxiliary Power Inverter (API):	A unit using solid state electronics to convert Primary power into 3 phase 230 VAC power for use by auxiliary equipment.

Item	**Definition**
ASI:	The Automatic Station Identification System.
AW0:	Weight of a fully functional, ready to run car.
AW1:	AW0 plus the weight of passengers when all seats are occupied
AW2:	AW1 plus the weight of standing passengers at 3 square feet of standee area per passenger.
AW3:	AW1 plus the weight of standing passengers at 1.5 square feet of standee area per passenger.
-B-	
BCIL:	Boston Center for Independent Living. A non-profit group concerned with improving the accessibility of public transit.
Blending:	In braking, a simultaneous dynamic and friction brake application with the effort of friction brake supplementing, as required, the maximum electrical braking to achieve the required total brake effort.
Brake Assurance:	The function provided within the ATP system that verifies a minimum braking effort has been achieved.
Brakes, Friction:	Mechanical system which applies pads on axle discs or wheel treads to provide braking effort through friction.
Braking, Dynamic:	Electrical braking in which the power generated by the traction motors, when driven as generators providing retardation effort, is either dissipated as heat by brake resistor grids (Rheostatic) or returned to the contact rail to help meet the power demand of other motoring cars (Regeneration).
Braking Effort:	Retarding force developed by the traction system, braking system or a combination of both systems.
Braking, Emergency:	Irrevocable braking to a full stop at the maximum design brake rate.
Braking, Full Service:	A brake application which obtains the maximum controlled, non-emergency brake rate consistent with the design of the propulsion and friction brake systems.
Braking, Regenerative:	Electric braking where the power generated by the traction motor, when driven as a generator, is conditioned and returned to the 600 volt DC third rail.
Braking System:	The system of wheels, motors, driving mechanism, friction brakes, controls, and appurtenances that retard the Transit Vehicle in response to input control signals.
Butt Line (BL):	Horizontal distance measured in inches on either side out from the vertical centerline that extends lengthwise through the vehicle. BL 0.0 is at the center line of the vehicle. BL is considered to be a datum plane and is assumed to be exact for the purposes of computation or reference.
-C-	
Cab Car:	The Car in a Married Pair with a fully equipped, functional cab area for Operator control.

Item	**Definition**
Camber:	The vertical deflection of the floor level midway between truck centers.
	(a) Positive Camber: The deflection is upward, i.e., the floor to rail distance is greater than that at the truck positions.
	(b) Negative Camber: The deflection is downward, i.e., the floor to rail distance is less than that at the truck positions.
Cant:	The tilt angle of each rail towards the track center line.
Car	Individual motorized rail car (one-half of a Married Pair)
Car Weight, Empty:	The weight of an empty Transit Vehicle ready to run. Also known as AW0.
Certified Weight Ticket:	A weight ticket produced automatically by a calibrated weight machine.
Coast:	The mode of operation of a Transit Vehicle or consist in which traction and braking are inactive.
Collision Posts:	Members of the end structure projecting upward from the underside of the underframe to provide protection to the interior of the car against penetration during a collision.
Component:	One replaceable part of the vehicle.
Component Testing:	Testing planned and conducted by the Contractor or sub-supplier during the development phase to ensure that the components of the planned product conform to the Contract Technical Requirements.
Configuration Management:	Discipline which assures that all equipment, software, and interfaces are identified by engineering data and that all changes thereto are controlled and recorded.
Console:	Control panel in the Operator's cab from which the Operator monitors and controls train operation.
Consist:	The quantity and specific identity of vehicles that make up a train.
Contact Rail, Third Rail	The power supply rail alongside the track from which the car current collector shoes collect electrical power for the operation of trains.
Contractual Deliverable Requirement List (CDRL):	CDRLs identify a portion of the items that are required to be submitted by the Contractor, to confirm compliance with Contractual obligations. CDRLs will be used by the Contractor to show the Authority how the design achieves compliance with the agreed Technical Requirements. CDRLs shall be formally submitted in accordance with the agreed-to and approved Program Schedule.
Contract Execution:	The date that the Authority and the Contractor affix their signatures to the Contract Documents.
Contractor:	The Prime Contractor solely responsible to the Authority for the quality and proper functioning of the vehicle(s) and all components; the person or persons, firm, partnership, corporation, or combination thereof which has entered into this Contract with the Authority to supply the vehicle(s).
Corner Post:	Car structural member that extends vertically from the floor structure to the roof structure, located at the No. 1 and No. 2 end surfaces with the side surface of the car.

Item	**Definition**
Corrective Maintenance:	Those actions performed, as a result of a failure, to restore an item to a specified condition.
Coupler:	A device for mechanically coupling Transit Vehicles together. This term is also applied to connectors, as in electric coupler and pneumatic coupler which couple electric and pneumatic trainlines together between Transit Vehicles.
Coupler, Electric Portion:	Equipment attached to the mechanical coupler for the purpose of achieving continuity of electrical control trainlines between cars.
Critical/Catastrophic Failure:	A failure which could result in an actual or potential major injury or fatality to patrons or personnel, or which could result in major damage to or loss of the system.
Critical Redundant/Back-Up Component Failure:	A failure point wherein the next successive failure could result in an actual or potential hazard to passengers, personnel, or the system.
Current Collector:	The device on a Transit Vehicle used to transfer electrical power from the stationary contact rail to the Transit Vehicle.
-D-	
Dead Band:	That portion of time or range of movement during which there is no change in output while an accompanying change in input is in effect.
Deadman Control:	A spring loaded device that detects cognizance of the train Operator.
Decibel:	Unit for expressing ratio of power levels in electrical communication or sound intensities.
Dependent Failure:	A secondary failure of equipment or hardware which prevents the system from performing its intended function. A failure is dependent when it is caused by a primary failure of associated equipment or hardware, component abuse, or incorrect maintenance procedures.
Design Safety:	Safety achieved by integration of safety features into the system design characteristics to prevent operation except in the manner intended to be safe.
Device:	An element of a component, consisting of parts and structure, which performs specific functions necessary to the operation of the component (bearings, batteries, connectors, and similar elements).
Diagnostic Test Equipment:	Portable computer based test equipment capable of simulating inputs and outputs for the purpose of troubleshooting vehicle equipment.
Dispatching:	The process of starting a train into revenue service from a terminal zone, transfer track, or passenger station.
Draft Gear:	The energy absorbing mechanism that attaches the coupler or drawbar to the anchorage.
Drawbar:	The Manually connected mechanical link coupler between cars of a married pair.
Drive:	A system consisting of one or several motors, their direct control equipment (power circuits), and the associated mechanical devices required to produce the desired output.
Dwell Time:	The period of time measured from the instant a train stops at a station until the instant it resumes moving.

Item	Definition
-E-	
Element:	One or more components capable of performing specified subsystem functions.
End Sill:	Lower body lateral structural element connecting side sills.
-F-	
Fail Safe:	A characteristic of a system which insures that any and all failure modes result in the system defaulting to a safe mode in regard to passengers, personnel, track, wayside and vehicle.

Item	Definition
Failure, Component or System:	A state of a component or system that requires replacement or adjustment to return to normal operation. 1. Failures discovered during inspection shall be counted as component or system failures. 2. Software failures that require the Authority's operating personnel to "re-boot" the system or take other actions to return the system to normal operation shall be counted as component failures even if no action is required by maintenance personnel. 3. System failures for which no trouble can be found (NTF) shall be counted as failures after the third NTF failure of the same system on the same car until the cause can be determined and corrected. 4. The replacement of consumable items such as filters, lamps, brake shoes, etc, shall not be considered as a component failure, unless the consumables fail to meet their specified life. 5. Failures caused by accidents, vandalism, operator or maintenance error shall not be counted. 6. Failures caused by improper operation, testing or maintenance due to faulty Contractor supplied documentation shall be counted as component or system failures. 7. Service failures are any failures that cause more than a 4 minute delay in service or unscheduled removal of a vehicle from service. a. Accidents, operator errors, failures caused by failure to perform approved maintenance procedures, and failures caused by environmental conditions exceeding those defined in he technical specification shall not be included.
Failure Mode Effects and Criticality Analysis (FMECA):	Study of a system and working interrelationships of its elements to determine ways in which failures can occur (failure modes), effects of each potential failure on the system element in which it occurs and on other system elements, and the probable overall consequences (criticality) of each failure mode on the success of the system.

Item	**Definition**
Failure Rate:	Failure rate is the frequency of independent equipment failures per equipment operating hour. Failure rate is expressed mathematically as: Failure Rate = Independent Equipment Failures/Equipment Operating Time
Fault Monitoring:	Automatic monitoring of train control logic for errors during service from any of the subsystems including brakes, traction, doors, air conditioning, etc.
Field Modification:	Any change, alteration, adjustment, or modification to the equipment or any part thereof not performed at the original manufacturer's facilities. Field Modifications shall be controlled and documented once conditional approval has been granted by the Authority.
Field Modification Instruction:	A formal document, accepted by the Authority, which defines/describes modifications and serves as a record of vehicle configuration.
Firmware:	The combination of a set of basic computer instructions, and the read only memory (ROM) that contains these instructions.
Flammability:	The ease, with which a material ignites and, once ignited, continues to burn.
Floor Height:	The vertical distance measured between the upper surfaces of the rail and car floor including floor covering when the unloaded car is in operational condition and stationary on level tangent track.
Frog:	Track structure at the intersection of two running rails to support wheels and provide passageways for their flanges as wheels on either rail pass through the intersection.
-G-	
Gage, Track:	The distance between the inside face of rails, usually measured 0.625" (16mm) below the top of the centerline of heads of running rails and at a right angle thereto. The MBTA System gauge is 4' 8.5" (1435mm).
-H-	
Handrails:	Safety appliances installed anywhere on the car, to assist in movement or provide a hand-hold during train motion.
Hazard:	Any real or potential condition or failure that can cause or contribute to an accident.
Headway:	The time separation between two trains, both traveling in the same direction on the same track. It is measured from the time the head end of the leading train passes a given reference point to the time the head end of the train immediately following passes the same reference point.
High Speed Circuit Breaker:	A current sensing switch which interrupts maximum fault currents to protect power circuits.
High Voltage:	Voltage level of primary power.
Hostler Panel:	Controls on the No. 1 of a Non-Cab Car provided for operation of the train. Normally used for yard moves.

Item	**Definition**
Hunting:	An oscillating motion of the truck and/or wheelsets during operation caused by wheel/rail dynamic forces and the reactions by the truck suspension.
-I-	
Incident:	An unexpected event which potentially degrades reliability, maintainability, and thereby system safety, and thereby increases the probability of an accident.
Independent Failure:	An independent failure is any incident, malfunction, or failure of equipment or hardware which prevents the unit from performing its intended function as required by these Technical Requirements. A failure is independent when it is not caused by the malfunction of other equipment or hardware, component abuse, or incorrect maintenance procedures.
Independent Service Failure:	An independent service failure is an incident, malfunction, or failure of equipment or hardware which not only prevents the unit from performing its intended function as required by these Technical Requirements, it also disrupts or delays scheduled revenue service for longer than three minutes or requires the removal of the vehicle from revenue service. Independent service failures are a special subset of the Independent failures category as defined above.
Interface:	The points where two or more subsystems, systems, persons, or firms must meet to ensure continuity of the project.
Interchangeable:	Any component or equipment capable of being selected at random from a batch supplied under the same title and substituted both physically and functionally for its counterpart on the complete equipment or system.
Interlock:	An electrical and/or mechanical means of preventing two or more actions from occurring simultaneously.
Inverter:	A solid state electronic means of converting a dc source of power into an ac voltage.
Irretrievable:	In braking, a condition imposed in which a brake application cannot be released until zero speed indication is attained.
-J-	
Jerk Rate:	The rate of change of acceleration or deceleration normally measured in miles per hour per second per second.
-L-	
Layover Time:	Period of time when revenue-ready Transit Vehicles are out of service, but available for use.
Leading Cab:	The controlling cab in a train-set.
Left Side:	Left side of the transit car as looking towards the No. 1 end from inside the car.
Line Contactor:	A relay switch used to disconnect the traction power system from the 600 volt line.

Item	Definition
Load Weight:	A signal derived from the load on the secondary suspension, used to regulate tractive effort and braking in proportion to car load.
Longitudinal:	Direction parallel to the normal direction of travel of a car.
Low Voltage:	Voltage level at which most auxiliary subsystems operate.
Low Voltage Power Supply:	A unit for converting primary power into a low voltage for use in charging the battery and supplying power to low voltage loads.
Low Voltage System:	A direct current (dc) system with a storage battery isolated from the primary high voltage system. It provides power for lights, controls and communication equipment in normal service and in emergency when primary power is lost.
Lowest Line Replaceable Unit (LLRU):	The lowest level assembly of components or piece parts to which a failure can be isolated and that can be readily replaced in its field application.
Line Replaceable Unit (LRU):	Components that are replaceable on the vehicle.
-M-	
Maintenance, Corrective:	Repair, adjustment, or replacement of components as a result of failures.
Married Pair:	Two semi-permanently coupled cars, including a Cab Car and a Non-Cab Car.
Master Controller:	The device to control power and braking from an operator's cab.
Mean Miles Between Failure (MMBF):	The average number of miles between in-service failures. An in-service failure is a failure that delays the train for more than 4 minutes or results in an off-loading of passengers.
Mean Distance Between Component Failure (MDBF):	The average number of miles traveled between independent component malfunctions or failures, regardless of time or status of train.
Mean Time Between Failure (MTBF):	The average equipment operating time per independent equipment failure. MTBF is the reciprocal of failure rate and is expressed mathematically as: MTBF = (Equipment Operating Time/Independent Failures) For the purposes of this contract, average time in service is 16 hours per day, 7 days per week, 48 weeks per year.
Mean Time to Repair (MTTR):	MTTR is the mean elapsed time required to perform the task of isolating an independent failure to the LLRU to remove and replace the malfunctioned LLRU and to verify proper equipment function. It is expressed in hours.
MIL-STD:	Military Standard.
Mock-Up:	A full scale model used to demonstrate preliminary design and/or specification compliance.
Model:	An object built to a smaller scale to demonstrate design.
-N-	
No. 1 End	The front end of the car. Cab end or hostler panel end.
No. 2 End	The rear end of the car.

Item	**Definition**
Non-Cab Car:	A car in a Married Pair with a hostler panel and additional passenger seats in the No. 1 end.
Nosing:	A sustained orientation of the truck in rotation to one side or the other during operation such that the truck and axles are not aligned with the track.
Notice to Proceed (NTP):	Written notice from the Authority to the Contractor to proceed with the Work.
-O-	
Operator’s Cab:	The compartment located at the No. 1 end of a Cab Car and equipped to provide proper facilities to enable operation of the train.
Operator, Train:	Onboard individual responsible for train operation.
-P-	
Performance:	The measure of output or results obtained by a component, system, person, team, and so forth, as in Performance Specification. Vehicle performance refers to performance which requires operation of a Transit Vehicle or Transit Vehicles, as in Performance Characteristics or Performance Testing.
Permanent Deformation:	Component undergoes a permanent change in shape.
Pilot Cars:	The first production Married Pair of each car type produced for the contact.
Pilot Train	The first 3 Married Pairs of each car type produced for the contact
Portable Test Unit (PTU):	Portable laptop computer loaded with software required to communicate with the microprocessor within a sub-component on the vehicle. ALL PTUs shall utilize a standard Ethernet port and a common interface cable. The PTU is a PC computer with a Windows based operating system.
Power:	High voltage DC power at a nominal voltage of 600 V supplied to the transit vehicle via interface between the current collector and the power rail.
Preventive Maintenance:	Those actions performed in an attempt to retain an item in a specified condition by providing systematic inspection, detection, and prevention of failure.
Primary Power:	High voltage DC power supplied to the Transit Vehicle via interface between the current collector and the contact rail.
Procedural Safety:	Safety achieved or enhanced by compliance with administrative or operational restrictions.
Profile Grade:	A straight line representing an established grade line, in relation to the horizontal.
Proof (Used in a suffix):	Apparatus is designated as splash-proof, dust-proof, and similarly, when so constructed, protected, or treated, that it's successful operation is not interfered with when subjected to the specified environmental condition.

Item	Definition
Prototype:	A unit built to test a new design and which performs essentially the same as a production unit.
-Q-	
Qualification Test:	Test performed using a preproduction or production item to determine whether or not the item complies with specified performance requirements.
Quality Assurance: (QA)	Actions, usually of an administrative nature, to ensure that end items will meet specified form, fit, function and finish criteria.
Quality Control:	The discipline which ensures the manufacture of a uniform product in accordance with specified requirements.
-R-	
Radio Frequency Identification Device (RFID):	Device installed on vehicle, sub-system or LRU that contains information related to the subject equipment. RFID tags are read with a radio frequency scanner.
Redundancy:	The existence in a system of more than one means of accomplishing a given function.
Relay, Vital:	A relay whose function is necessary for the safe operation of the train and whose mode of failure is fail-safe.
Reliability:	The probability of performing a specified function without failure and within design parameters for the period of time intended under actual operating conditions.
Requirements:	The criteria which must be met when designing the Transit Vehicle.
Residual Hazards:	Hazards for which safety or warning devices and special procedures cannot be provided to counteract the hazard.
Revenue Service:	Service on routes established for train use by the public.
Right Side:	Right side of the car as looking towards the No. 1 end from inside the car.
Roll:	Rotational motion of a Transit Vehicle body about a longitudinal axis.
-S-	
Safety:	Freedom from those conditions that can cause injury or death to personnel, or damage to or loss of equipment or property.
Safety Critical Elements:	Hardware, firmware, and software which provide safety critical functions shall be designated safety critical elements.
Safety Critical Failure:	A safety critical failure is failure of hardware, firmware, or software which is or results in, a critical/catastrophic hazard.
Safety Critical Functions:	Functions, the failure of which could be or result in a critical/catastrophic hazard, shall be designated safety critical.
Semi-Permanent Coupler:	The solid drawbar that attaches a Cab Car to a Non-Cab car. It includes electrical and pneumatic trainlines between the two cars.
Scheduled Maintenance:	Maintenance actions performed on a calendar or operating hour basis. Preventive and servicing maintenance are sub-categories of scheduled maintenance.

Item	**Definition**
Service Proven:	Car components and/or systems that have documented history of reliability in rail car service at least equal to the performance requirements of this specification. The historic data shall be from similar environmental conditions to those encountered on the Red and Orange Lines for a period of 2 years and a distance of ten times the claimed MTBF or MDBF.
Servicing Maintenance:	Servicing maintenance consists of those actions to replenish consumables.
Shunt Trip:	Alternative means of opening a circuit breaker by remote control (other than by self sensing of overload).
Side Sills:	Longitudinal rails which form the bottom chord of the side frames.
Slide, Wheel:	The condition existing when the rotational speed of the wheel is slower than that for pure rolling contact between the tread and the running rail.
Speed, Balancing:	The steady state speed attained by the train when resisting forces exactly equal to available tractive forces.
Speed Limit	The upper limit of train speed as permitted by the ATP or propulsion equipment.
Speed Limit, Civil:	The maximum design speed allowed in a specific zone for the comfort of passengers aboard a train and at station platforms.
Speed Sensor:	A device for accurately detecting the rotational speed of a toothed wheel on an axle or gearbox.
Spin, Wheel:	During positive tractive effort, the condition existing when the rotational speed of the wheel is faster than that for pure rolling contact between the tread and the running rail.
Station (STA):	Horizontal distance measured in inches aft from the face of the No. 1 end mechanical coupler. STA 0.0 is at the No. 1 end coupler face. STA is considered to be a datum plane and is assumed to be exact for the purposes of computation or reference.
Step Signal:	A signal having a constant value prior to a certain instant and a different constant value immediately thereafter.
Stop, Emergency:	The stopping of a train at the emergency brake rate by an emergency brake application which is irretrievable once initiated
Stop, Full Service:	The stopping of a train at the full service brake rate by a full service brake application.
Subsystem:	A subsystem comprised of elements interconnected within a system to perform a specific function.
Superelevation:	On a curve, the vertical distance, measured in inches that the outer rail is above the inner rail.
System:	A composite of equipment used together as an entity and capable of performing or supporting an operational role.

Item	Definition
System Safety:	Optimization of the degree of safety within the constraints of operational effectiveness, time, and cost attained through specific application of systems safety management and engineering principles throughout all phases of a system's life cycle. Systems safety is evolved from and represents the integration of safety principles through the system. Systems safety as a discipline refers to systems safety management and engineering to provide surety that the environment, the patrons, personnel, or equipment are free from inadvertent or unexpected events which may result in injury to patrons or personnel, or damage to the equipment.
Safety Engineering:	An element of systems engineering that involves the application of scientific and engineering principles to the timely identification of hazards, and initiation of those actions necessary to prevent, minimize, or control hazards within a system. It draws upon professional knowledge and specialized skills in the mathematical, physical, and related scientific disciplines, together with the principles and methods of engineering design and analysis to specify, predict, and evaluate the safety of the system.
Systems Safety Management:	Program management which ensures the accomplishment of systems safety tasks including identification of the systems safety requirements; planning, organizing, and controlling those efforts which are directed towards achieving the safety goals; coordinating with other (system) program elements; and analyzing, reviewing, and evaluating the program to ensure effective and timely realization of the systems safety objectives.
-T-	
Tamperproof Fastener:	Fasteners that are designated as tamperproof when they are selected so that they cannot be easily loosened with common tools.
Third Rail:	See Contact Rail.
Third Rail Shoe:	See Current Collector.
Tight (Used as Suffix):	Apparatus is designated as watertight, dust-tight, and similarly, when so constructed that the enclosing case will exclude the specific material.
Time, Dead:	Time from the initiation of a step change of the control signal to the beginning of change of the controlled variable.
Time, Down:	The lapsed time during which equipment is not capable of doing useful work because of maladjustment, malfunction, or maintenance in progress.
Time, Reaction:	Time from the initiation of a step change of control signal to the first attainment of the new steady-state value of the controlled variable, within a designated accuracy.
Time, Recovery:	The time required for a system or condition to return to its original state (or some stated percentage of its original value) after being disrupted or destabilized.
Time, Warm-up:	The elapsed time from application of power to an operable device until said device is capable of performing its intended function.

Item	**Definition**
Top of Rail (TOR):	A height datum coinciding with the upper surface of the running rails.
Tractive Effort:	Propelling or braking force developed by the propulsion (positive) or braking system (negative at the wheel/rail interface.
Traction Inverter:	Equipment for converting Primary power into a suitable voltage of varying frequency and amplitude for connection to the traction motors.
Traction System:	The system of wheels, motors driving mechanism, controls, and appurtenances which provide tractive effort for a Transit Vehicle in response to input control signals.
Train-set:	Multiple Married Pairs operating as a single entity for carrying passengers.
Train Control:	An on-board control system for managing train movement and enforcing train safety, also a wayside system for directing train operations.
Trainline:	The means of sending a signal to all cars in a train-set via a continuous electrical circuit connected through appropriate coupling devices.
Tram:	A condition of truck geometry in which the centers of the journal bearings represent the corners of a rectangle.
Trip Cock:	A mechanical device located on the train which when hit by a trip stop results in an emergency brake application.
Transverse:	Direction perpendicular to the normal direction of travel of a vehicle.
Truck:	The assembly containing motors, drive train, vehicle suspension and brakes which swivels beneath each end of a car and supports its mass on the rails.
-U-	
Ultimate Strength:	The limit of the ability of a structural member to resist fracture or collapse.
Underframe:	The horizontal structure at the bottom of a carbody which supports the car, and to which undercar equipment is hung.
-V-	
Vehicle	Married Pair of Cab Car and Non-Cab Car
Vital Function:	A function in a safety-critical system that is required to be implemented in a fail-safe manner.
-W-	
Weights, Actual:	The measured weights of finished Transit Vehicles ready to run.
Weights, Assigned:	The loaded Transit Vehicle categories assigned as the basis for traction system design and for subsystem and Transit Vehicle testing.
Wheelset:	A pair of wheels mounted on an axle complete with journal bearings, drive components and ground-brushes.
Windscreens:	Screens located on either side of doors extending into passenger compartment to form a vestibule and protect passengers in adjacent seats.

Item	Definition
Windshield:	Windows on the front face of the car.
-Z-	
Zero Speed:	Vehicle velocity of less than 1 miles/hr.

1.08.02. Abbreviations & Acronyms

A. The following is a list of abbreviations and acronyms used in the Technical Requirements. The list is not intended to be all inclusive.

Acronym	Expanded Description of Acronym or Abbreviation
-A-	
AACP	Automatic Announcement Control Panel
AAR	Association of American Railroads
AASCS	Automatic Announcement/Sign Control System
AATCC	American Association of Textile Chemists and Colorists
AC	Alternating Current
AFE	Authority Furnished Equipment
AFBMA	Anti-Friction Bearing Manufacturers Association
ADA	Americans with Disabilities Act
ADU	Aspect Display Unit
AF	Audio Frequency
AGMA	American Gear Manufacturing Association
AIAA	The American Institute of Aeronautics and Astronautics
AISI	American Iron and Steel Institute
ALS	Automatic Line Supervision
ANSI	American National Standards Institute
ANSYS	Software package used in finite element analysis.
API	Auxiliary Power Inverter
APTA	American Public Transportation Association
ASHRAE	American Society of Heating, Refrigerating & Air Conditioning Engineers
ASI	Automatic Station Identification
ASIC	Application-Specific Integrated Circuit
ASME	American Society of Mechanical Engineers
ASQ	American Society for Quality
ASR	Automatic Speed Regulation
ASTM	American Society for Testing and Materials
ATA	Air Transportation Association of America’s
ATAS	Automatic Train Announcement System
ATOR	Above Top of Rail
ATC	Automatic Train Control
ATO	Automatic Train Operation
ATP	Automatic Train Protection

Acronym	Expanded Description of Acronym or Abbreviation
AW0	See definitions above
AW1	See definitions above
AW2	See definitions above
AW3	See definitions above
AWG	American Wire Gage
AWS	American Welding Society, Inc.
-B-	
BCO	Brake Cutout Valves
BL	Butt Line
BRK	Drive/Brake Mode Signals
BTE	Bench Test Equipment
BTU	British Thermal Unit
BVMU	The Brake Valve Manifold Unit
-C-	
°C	Degree Centigrade
CAD	Computer Aided Design
CC/FIMS	Car Control/Fault Identification and Monitoring System
CCP	Communications Control Panel
CCR	Communications Control Rack
CCTV	Closed Circuit Television
CCU	Communications Control Unit
CDR	Conceptual Design Review
CDRL	Contract Deliverable Requirement List
CD-ROM	Compact Disc Read-Only Memory.
CEN	Communications Ethernet Network
CFM	Cubic Feet per Minute
CFR	Code of Federal Regulations
CIC	Crew Intercom
CMMI	Capability Maturity Model Integration.
CMMI-ACQ	Capability Maturity Model® Integration Model for Software Acquisition.
CMMI-DEV	Capability Maturity Model Integration for Software Development
CNC	Lathe is a lathe that is computer controlled. A machining program is written to achieve complex designs and tight tolerances
COTS	Commercial Off The Shelf
CPLD	Complex Programmable Logic Device
CPM	Critical Path Method
CPU	Central Processing Unit
CRC	Cyclic Redundancy Check.
-D-	
Ds	Specific Optical Density
dBA	Sound Pressure level in decibels, A-weighted

Acronym	Expanded Description of Acronym or Abbreviation
DBDD	Database Design Description
DC	Direct Current
DIN	Deutsches Institut Für Normung
DOD	Department Of Defense
DOT	U.S. Department of Transportation
DPST	Double Pole Single Throw
DTE	Diagnostic Test Equipment
DVD	Digital Video Disc
-E-	
E/W	East/West
ECN	Engineering Changes
EDACS	The Enhanced Digital Access Communication System
EEPROM	Electronic Erasable Programmable Read Only Memory
EIA	Electronic Industries Association
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
EMV	Emergency Magnet Valves
EP	Electric Proportional
ERS	Event Recorder System
ES	Ending Stations
-F-	
°F	Degree Fahrenheit
FAI	Unit First Article Inspection
FBCU	Friction Brake Control Unit
°FDB	Degrees Fahrenheit Dry Bulb
FDR	Final Design Review
°FWB	Degrees Fahrenheit Wet Bulb
FAA	Federal Aviation Administration
FAI	First Article Inspection
FCC	Federal Communications Commission.
FEA	Finite Element Analysis
FED-STD	Federal Standard
FIFO	First In, First Out,
FIMS	Fault Identification and Monitoring System
FMEA	Failure Mode and Effect or Analysis
FMECA	Failure Modes Effect and Criticality Analyses
FPGA	Field-Programmable Gate Array
FPM	Feet per minute
FRA	Federal Railroad Administration
FRB	Failure Review Board
FRP	Fiberglass Reinforced Plastics
FS	Full Service
FTA	Federal Transit Administration

Acronym	Expanded Description of Acronym or Abbreviation
-G-	
g	Acceleration - 32.2 feet per second per second (9.82 meters per second per second)
-H-	
HDL	Hydrodynamic Labyrinth
HDDR	High Density Data Radio
HIC	Head Injury Criteria
HID	High Intensity Discharge
HMM	Heavy Maintenance Manual
HP	Horse Power
HPPL	High Performance Photo Luminescent
Hr.	Hour
HSCB	High Speed Circuit Breaker
HSLA	High Strength, Low Alloy
HTML	Hypertext Markup Language
HVAC	Heating, Ventilation and Air Conditioning
Hz	Cycles per second
-I-	
I/O	Input/Output
IC	Intercommunication
IC's	Integrated Circuits
ICD	Interface Control Document
ICEA	Insulated Cable Engineers Association
ID	Identification
IDR	Intermediate Design Review
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers, Inc.
IFI	Industrial Fasteners Institute
IGBT	Insulated Gate Bipolar Transistor
I/O	Inputs/Outputs
IPC	The Institute for Interconnecting and Packaging Electronic Circuits
IPCEA	Insulated Power Cable Engineers Association
ISO	International Standards Organization
-K-	
kHz	KiloHertz
-L-	
LabVIEW™	Laboratory Virtual Instrumentation Engineering Workbench
LCD	Liquid Crystal Diode
LED	Light Emitting Diode
LLRU	Lowest Line Replaceable Unit
LLEPM	Low Level Exit Path Marking

Acronym	Expanded Description of Acronym or Abbreviation
LRU	Line Replaceable Unit
LVPS	Low Voltage Power Supply
-M-	
M/A-COM	a developer and producer of radio, microwave, and millimeter wave semiconductor devices and components
MBTA	Massachusetts Bay Transportation Authority
MCM	Manuals and Catalog Manager
MCS	Manual Cab Signal
MCSS	Master control Selector Switch
MDBCF	Mean Distance Between Component Failure
MH/VM	Direct Man-Hours Per Vehicle Mile
MHz	megahertz
MIL-HDBK	Military Handbook
MIL-STD	Military Standard
MMBF	Mean Miles Between Failure
MMIS	Material Management Information System
MOSFET	Metal Oxide Semiconductor Field Effect Transistor
MPCEN	Married Pair Communications Ethernet Network
MPEDN	Married Pair Ethernet Diagnostic Network
MPEG-4	a collection of methods defining compression of audio and visual (AV) digital data
MPH	Miles Per Hour
MPI	Magnetic Particle Inspection
MPM	Maintenance Planning Manual
MQR	Monthly Quality Report
MRS	Manual Release Switch
MTBCF	Mean Time Between Component Failure
MTBF	Mean Time Between Failures
MTCN	Monitoring and Train Control Network
MTTR	Mean Time To Repair
MVB	Multifunction Vehicle Bus
-N-	
N/S	North / South
NAL	Net Axle Lateral Force
NASA	National Aeronautics and Space Administration
NASTRAN	A finite element analysis (FEA) program that was originally developed for NASA in the late 1960s under United States government funding
NBS	National Bureau of Standards
NEC	National Electrical Code
NEMA	National Electrical Manufacturers Association
NFL	No Field Lubrication
NFPA	National Fire Protection Association
NiCd	Nickel Cadmium Battery

Acronym	Expanded Description of Acronym or Abbreviation
NIST	National Institute of Standards and Technology
NPT	National Pipe Thread
NTP	Notice To Proceed
NVR	Network Video Recorder
-O-	
OCC	Operations Control Center
OEM	Original Equipment Manufacturer
OM	Operator's Manual
OSI	The Open Systems Interconnection Reference Model
-P-	
PA	Public Address
PBTE	Power Bench Test Equipment
PC	Printed Circuit
PCB	Printed Circuit Board
PCE	Propulsion Control Equipment
PCI	Peripheral Component Interconnect
PDR	Preliminary Design Review
PDRL	Proposal Data Requirement List
PECE	Propulsion Electronic Control Equipment
PEI	Passenger Emergency Intercom
PHA	Preliminary Hazards Analysis
PLD	Programmable Logic Devices
PQP	Project Quality Plan
PROM	Programmable Read Only Memory
psig	Pounds per Square Inch - Gage
PTU	Portable Test Unit
PVC	Polyvinyl Chloride
-Q-	
QA	Quality Assurance
QC	Quality Control
QM	Quality Manager
QSM	Quality System Manual
-R-	
RAL	Color matching system
RAM	Reliability, Availability and Maintainability
RAMS	Reliability, Availability, Maintainability, and Safety
RDT	Reliability Demonstration Testing
RDI	Radio Data Interface
RF	Radio-Frequency
RFC	Radio Frequency Compatibility
RFI	Radio Frequency Interference
RFID	Radio Frequency Identification Device

Acronym	Expanded Description of Acronym or Abbreviation
RFP	Request for Proposal
RMM	Running Maintenance Manual
ROM	Read Only Memory
ROW	Right of Way
-S-	
SAE	Society of Automotive Engineering
SCCP	Software Configuration Control Plan
SCMP	Software Configuration Management Plan
SD	Software Documentation
SDD	Software Design Description
SDP	Software Development Plan
SID	Software Interface Document
SINAD	Signal to Noise And Distortion
SPL	Sound Pressure Level
SPMP	Software Project Management Plan
SQAP	Software Quality Assurance Plan
SRS	Software Requirement Specification
SRTM	Software Requirement Traceability Matrix
SSHA	Subsystem Hazards Analysis
STA	Station Line
STD	Standard
STPr	Software Test Procedure
STP	Software Test Plan
STR	Software Test Report
SUM	Software User Manual
SVD	Software Version Description
SVVP	Software Verification and Validation Plan
SVVR	Software Verification and Validation Report
-T-	
TBD	To be determined
TBU	Tread Brake Units
TEN	Train Ethernet Network
TENV	Totally Enclosed, Non-vented motors
THD	Total Harmonic Distortion
TIR	Total Indicated Runout
TOR	Top Of Rail
T	Technical Specification
TS	Train Switches
TWC	Train-to-Wayside Communications
-U-	
UL	Underwriters Laboratories Inc.
UMTA	Urban Mass Transportation Administration, U.S. Department of Transportation

Acronym	Expanded Description of Acronym or Abbreviation
US	United States
USB	Universal Serial Bus
UUT	Unit Under Test
UV	Ultra Violet
-V-	
VAC	Volts, Alternating Current
VDC	Volts, Direct Current
VLC	Voltage Limiting Chopper
VMD	Vehicle Monitoring Display
VMS	Vehicle Monitoring System
VMU	Vehicle Monitoring Unit
VS	Vehicle Switches
-W-	
WTB	Wire Train Bus
WL	Water Line

1.09: CDRL ITEMS REFERENCED

CDRL 01-01, “Renderings”, (Ref: T 01.05.01.C)

CDRL 01-02, “Models”, (Ref: T 01.06.01.A)

CDRL 01-03, “Virtual Mock-Ups”, (Ref: T 01.07.02.A)

CDRL 01-04, “Front End Mock-Up”, (Ref: T 01.07.03.A)

CDRL 01-05, “Passenger Area Mock-Up”, (Ref: T 01.07.04.A)

CDRL 01-06, “Underframe Mock-Up”, (Ref: T 01.07.05.A)

PART T 02.00
VEHICLE DESIGN REQUIREMENTS

Table of Contents

2.01: GENERAL

2.01.01. General Vehicle Requirements

A. The requirements specified in this section provide general performance criteria of the vehicles. Additional requirements for each subsystem are defined in the corresponding specification section.

B. Not used.

C. Not used.

D. Vehicle design (including mechanical coupling, anti-climber height, structural strength, etc.) shall be compatible with existing vehicles. The new vehicles will not be operated in consists with existing vehicles, so electrical and pneumatic coupling/trainline compatibility shall not be required.

E. The #4 Red Line and #14 Orange Line cars will be operated as train sets comprised of Married Pairs that include a Cab Car and a Non-Cab Car.

1. A 6-car, 3 Married Pair train with a Cab Car on each end will be the maximum train-set for normal service operation.

2. The 4-car 2 Married Pair train with a Cab Car on each end will be the minimum train-set for normal service operation.

F. In emergencies up to a 12 car train may be used, where one train of equal or longer size may be used for pushing or pulling a disabled train of up to 6 cars..

G. Non-Cab Cars shall have a hostler panel to enable yard moves and rescues from either end of the Married Pair.

H. A train shall be operable at restricted speed from any hostler panel or cab in the train in the event that the controls in the lead Cab Car are disabled.

I. For vehicles on each line:

1. Both Cab and Non-Cab cars shall be fully equipped with propulsion, braking, HVAC, auxiliary power, etc.

2. Shared sub-systems shall be limited to the Vehicle Monitoring System, air compressor, and battery (each car's low voltage power supply shall charge the common battery).

   a. As a result of a failure, cars may share Auxiliary Power Units and Low Voltage Power Supplies.

3. Drawbars shall be utilized between the two cars (No. 2 ends) of the Married Pair.

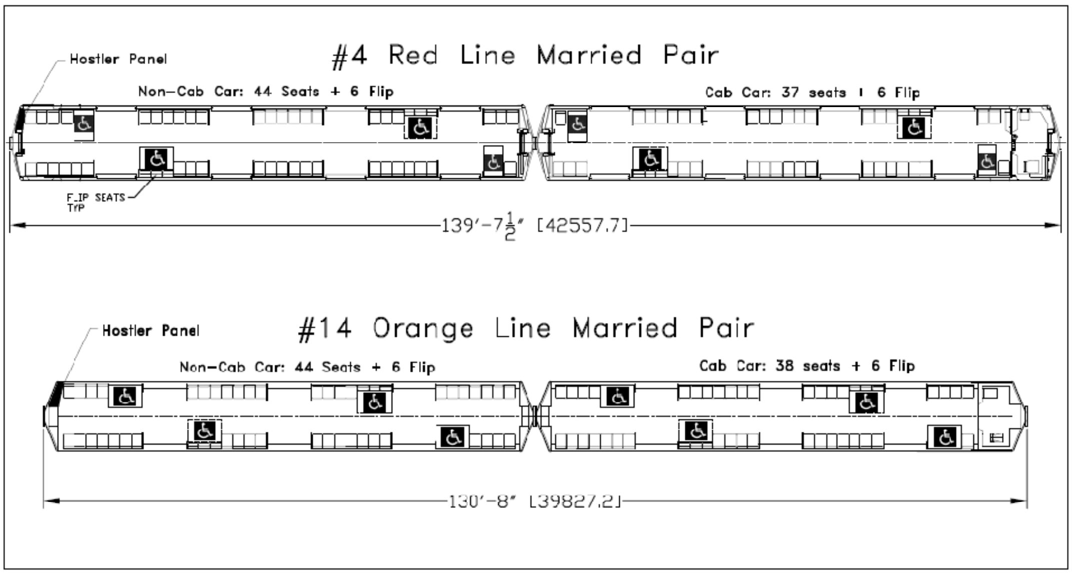
4. Electro-pneumatic automatic couplers shall be fitted on the No. 1 ends.

J. New Red and Orange Line cars shall be designed to be as similar to each other as possible. All subsystems, to the maximum extent possible, shall be identical. Where possible, software modification shall be utilized to account for the differences between Red and Orange Line cars. The contractor shall prepare a report that documents all major subsystem parts that will not be common on the two lines, with technical and commercial justification as to why common parts would be a disadvantage to the Authority. [CDRL 02-01]

K. Side door configuration shall be as follows:

1. Red Line vehicles shall have 4 doors per side per car.

2. Orange Line vehicles shall have 3 doors per side per car.



L. The Red and Orange Lines are made up of a combination of surface, elevated and underground track, powered by a 600 volt DC 3rd rail.

M. Trains will operate in service at speeds up to 63 miles per hour. Cars shall be designed and qualified at a maximum speed of 70 miles per hour.

N. The cars shall be designed to run a minimum of 80,000 miles per year with a minimum service life of 30 years based on performance of approved scheduled maintenance and overhauls. Carbody and truck structures shall be designed to outlast all other systems.

2.01.02. Current Vehicle Dimensional Data

A. The dimensions shown below are based on existing vehicles currently in operation, with the exception of end doors and side door openings. Contractors may propose minor modifications to these dimensions that accommodate equipment and clearance envelope compatibility, for consideration by the Authority:

B. All heights are Above Top of Rail (ATOR) with new wheels. Slight variations between proposed vehicles and existing vehicles may be considered by the Authority.

Description	Red Line #4	Orange Line #14
Length - draw bar face to coupler face	69’ 9 ¾” ± 3/8” (21.279 m ± 9 mm)	65’ 4” ± 3/8” (19.914 m ± 9 mm)
Height - Top of anti-climbers	4’ 1” ±1/8” (1244.6 mm ± 3 mm)	3’ 8 3/4” ± 1/8” (1136.7 mm ± 3 mm)
Length - over anti-climbers	69’ 6” ± 3/8” (21.184 m ± 9 mm)	65’ 0” ± 3/8” (19.812 m ± 9 mm)
Vehicle width at threshold	9’ 6” ± 1/8” (2.896 m ± 3 mm)	8’ 7” ± 1/8” (2.616 m ± 3 mm)
Vehicle width at underframe	7’ 11 23/32” (2.431m)	9’ 3/4’’ (2.762m)
Max vehicle width	10’ 0” ± 1/8” (3.048 m ± 3 mm)	9’ 3” ± 1/8” (2.819 m ± 3 mm)
Height - top of floor new wheels to top of rail (TOR), (AW0) after settlement of springs	4’ 1” + 1/4” – 0” (1244.6 mm + 6 mm - 0 mm)	3’ 8 3/4” + 1/4”-0” (1136.7 mm + 6 mm - 0 mm)
Height - top of threshold from TOR	4’ 1/2” + 1/4” – 0” (1231.9 mm + 6 mm - 0 mm)	3’ 8 ” + 1/4”- 0” (1117.6 mm + 6 mm - 0 mm)
Height – finished floor to bottom of side window opening	2’ 10” ± 1/8” (863.6 mm ± 3 mm)	2’ 10” ± 1/8” (863.6 mm ± 3 mm)
Height - finished floor to top of side window opening	6’ 1/4” ± 1/8” (1752.6 mm ± 3 mm)	6’ 1/4” ± 1/8” (1752.6 mm ± 3 mm)
Height - floor to top of windshield and Number 2 end windows	6’ 7/8” ± 1/8” (1851.0 mm ± 3 mm)	6’ 7/8” ± 1/8” (1851.0 mm ± 3 mm)
Height - TOR to top of roof car line	12’ 3 3/4” + 0” - 1/8” (3752.9 mm + 0 mm – 6 mm)	11’ 11 3/4” + 0” - 1/8” (3752.9 mm + 0 mm – 6 mm)
Height – TOR to center of coupler head, new wheels	2’ 7 5/8” ± 1/4” -0” (803.3 mm ± 6 mm)	2’ 6 ¼” + 1/4” -0” (768.4 mm ± 6 mm)
Distance between truck centers	51’ 0” ± 1/4" (15.545 m ± 6 mm)	46’ 6” ± 1/4” (14.173 m ± 6 mm)
Truck wheel base	6’ 10” (2.083 m)	6’ 10” (2.083 m)

Description	Red Line #4	Orange Line #14
Wheel Diameter new	28" + 1/4" - 0" (711.2 mm + 6 mm – 0 mm)	28" + 1/4" - 0" (711.2 mm + 6 mm – 0 mm)
Minimum worn Wheel Diameter	26" + 1/8"- 0" (647.7 mm +3.2 - 0 mm)	26"+ 1/8"- 0" (647.7 mm +3.2 - 0 mm)
Clear width of end door openings (minimum)	30" (762 mm) minimum	30" (762 mm) minimum
Width of Clear side door openings	64" (1626 mm) minimum	64" (1626 mm) minimum
Height door openings over floor	6' 3" ± 1/8" 1.905 m ± 6 mm	6' 3" ± 1/8" 1.905 m ± 6 mm
Height floor to ceiling	7' 2" ± 1" (2.184 m ± 25 mm)	7' 1" (2.159m) minimum
Camber @ AW3	+ 1/4" - 0" (+ 6 mm - 0 mm)	+ 1/4" - 0" (+ 6 mm - 0 mm)
Maximum coupler swing	Sufficient for 110' (33.53 m) horizontal curve	Sufficient for 110' (33.53 m) horizontal curve

Table 2-1 Current Vehicle Dimension Data

2.01.03. Track Conditions

A. The Authority's Track Maintenance and Safety Standards for Heavy Rail Vehicles is provided in the appendix of the specification for reference and to provide the Contractor with the basic guidelines followed by the Authority in the construction and maintenance of the Right of Way (ROW).

1. These documents should be referenced as a guide, and not taken as absolute or worst case conditions encountered in the ROW. Actual track conditions may exceed the limits listed here before being detected and corrected (or a speed restriction enforced).

B. The Authority's Book of Standard Trackwork Plans is also provided for information in the appendix. The Book addresses the materials utilized and guidelines followed in construction of the ROW. The 115 lb RE rail used on the Red and Orange Line is shown in drawing number 300.

1. It should be noted that the Authority is regularly valuating/experimenting with new track materials not identified in the Book. A list of all materials under evaluation at the time of contract award will be provided to the Contractor by the Authority.

C. Present Track conditions and track geometry are provided in the appendix of the specification for reference. The Contractor shall validate the data as required in T 11, Trucks. The following Track Design Parameters may not reflect current conditions, but can be used for nominal values. See T 11, Trucks, for geometry data to be used for truck and vehicle modeling:

Description	Red Line	Orange Line
Radii of minimum horizontal curves	125’ (38.1 m) - yard 250’ (76.2 m) - mainline	120’ (36.6 m) yard 440’ (134.1 m) mainline
Corresponding superelevation (maximum)	1” (25.4 mm) - yard 2 1/2” (63.5 mm) - mainline	1” (25.4 mm) - yard 1 1/2” (38.1 mm) - mainline
Maximum superelevation	6” (152.4 mm)	6” (152.4 mm)
Corresponding curve radius	1300’(396 m)	1800’ (549 m)
Radii of minimum reverse curve at track centerline	Mainline 400’ (122 m) Yard 150’ (46 m) - back to back 150’ (46 m) turnouts	Mainline 440’ (134 m) Yard 150’ (46 m) - back to back 150’ (46 m) turnouts
Minimum tangent between reverse curves	Mainline 30’ (9.1 m) - back to back No. 10 Turnouts Yard 12.5’(3.8 m) - back to back No. 6 Turnouts	Mainline 12.5’ (3.8 m) between back to back No. 6 Turnouts Yard 12.5’ (3.8 m) between back to back No. 6 Turnouts
Radii of minimum vertical curves	Approximately 2000’ (610 m) for both crest and sag curves	Approximately 3750’ (1143 m) for sag curves, Approximately 2280’ (695 m) for crest curves
Maximum vertical grade	4% (1200’ (366 m) long)	5.6% (approximately 60’(19 m) long) 4%, (approximately 750’(229 m) long)
Running Rail nominal gage	4’ 8 1/2” (1435 mm)	4’ 8 1/2” (1435 mm)
Running Rail nominal gage on curves greater than 1000’	4’ 8 1/2” (1435 mm)	4’ 8 1/2” (1435 mm)
Running Rail nominal gage on curves less than 1000’ but greater than 125'	4’ 8 7/8” (1444.6 mm)	4’ 8 7/8” (1444.6 mm)
Running Rail nominal gage on curves	4’ 9 1/4”	4’ 9 1/4”

Description	Red Line	Orange Line
less than 125'	(1454.2 mm)	(1454.2 mm)
Height of third rail above top of running rail	5 15/16” (150.8 mm)	5 15/16” (150.8 mm)
Variance in third rail height	+1/2” (12.7 mm), - 1” (25.4 mm)	+1/2” (12.7 mm), - 1” (25.4 mm)
Nominal horizontal distance between third rail and running rail centerline to centerline	21 25/32” (553.3 mm)	21 25/32” (553.3 mm)
Trip cock height above top of rail (maximum)	2 5/8” (66.7 mm)	2 5/8” (66.7 mm)
Trip cock height above top of rail (minimum)	2 3/8” (60.3 mm)	2 3/8” (60.3 mm)
Horizontal distance from centerline of third rail to gage of running rail	20 7/16” (519.1 mm)	20 7/16” (519.1 mm)
Variation in distance from centerline of third rail to gage of running rail	+/- 1/2” (+/- 12.7 mm)	+/- 1/2” (+/- 12.7 mm)

Table 2-2 Track Conditions

2.01.04. Environmental Conditions

A. The vehicle shall be capable of operation at performance levels under the following environmental conditions:

1. Minimum ambient temperature -20°F (-29°C)
2. Maximum ambient temperature 120°F (49°C)
3. Humidity 10 to 100%
4. Continuous rainfall rate 4 in/hr (10 cm/hr)
5. Continuous snowfall rate 5 in/hr (12.7 cm/hr)
6. Continuous wind 40 mph (64 kph)
7. Gusting wind 70 mph (113 kph)
8. Fording:
   a. Water 3 in (76 mm) above top of rail
   b. Snow 12 in (305 mm) above top of rail

2.01.05. Clearances

A. The clearance requirements below shall be upheld under the worst case combinations of wheel wear, suspension deflection, passenger loading, crest, sag and horizontal curves:

Description	Red & Orange Line
Vertical and horizontal clearance	In accordance with clearance envelope drawings in appendix
Under floor equipment – Vertical Clearance from top of rail	4.75 inches (120.6 mm)
Under floor equipment Clearance from third rail	5 inches (127 mm) vertical for components up to 35" from third rail 4.75 inches above top of rail for components greater than 35" from third rail.
Truck frame mounted equipment – Vertical clearance from top of rail	2.75 inches (70 mm),
Truck frame mounted equipment - Clearance from third rail	3.0 inches (76.2 mm) vertical, 3.5 inches (88.9 mm) lateral

Table 2-3 Clearances

B. Truck and underframe clearances shall be sufficient to allow wheel truing with the Authority's existing wheel truing machines without removal of the truck from the car or any components from the truck or the vehicle. Wheel truing equipment information will be furnished to the contractor during design review.

C. Carbody and truck design shall accommodate jacking on existing Authority car hoists. Hoist equipment information will be furnished to the contractor during design review.

2.01.06. Weight

A. Infrastructure limitations on both the Red and the Orange Line vehicles dictate an absolute AW3 weight limit on the vehicles. Limits are shown in table No. 2-4 and No. 2-5 below.

B. Final ready-to-run vehicle weight (including consumables such as washer fluid) shall be recorded on calibrated load cells and included in the Car History Book.

1. Actual measured weights of all major components used in the vehicle production shall also be included with each delivered car.

2.01.07. Weight Management Program

A. Weight limits on this procurement are absolute due to infrastructure limitations. Overweight vehicles will not be accepted by the Authority. Within 30 days of Notice To Proceed (NTP), the Contractor shall present a Weight Management Program to the Authority for review and approval. [CDRL 02-02]

B. The program shall include monthly weight reports detailed to the Line Replaceable Unit level, weight targets for new systems and weight reduction measures currently underway. Weight reports shall be included as part of the Monthly Progress Report, commencing 60 days after NTP.

C. As production or prototype material arrives at the Contractor's site, estimated weights shall be replaced with actual values. As components arrive that exceed their estimate, mitigation plans shall be selected and included in the following month's Weight Management Program.

D. The Contractor may propose weight saving options to the specification requirements. Alternatives that do not detract from the quality and reliability of the vehicle will be taken into consideration by the Authority.

2.01.08. Weight Limits

ORANGE LINE CAB CAR			**ORANGE LINE NON-CAB CAR**		
Load	**Passengers**	**Weight**	**Load**	**Passengers**	**Weight**
AW0	0	75,125 lbs.	AW0	0	72,800 lbs
AW1	38	81,015 lbs	AW1	44	79,620 lbs
AW2	132	95,585 lbs	AW2	142	94,810 lbs
AW3	225	110,000 lbs	AW3	240	110,000 lbs

Table 2-4 Orange Line Weight Limits

RED LINE CAB CAR			**RED LINE NON-CAB CAR**		
Load	**Passengers**	**Weight**	**Load**	**Passengers**	**Weight**
AW0	0	83,150 lbs.	AW0	0	80,205 lbs
AW1	37	89,350 lbs	AW1	44	87,025 lbs
AW2	154	107,020 lbs	AW2	166	105,935 lbs
AW3	270	125,000 lbs	AW3	289	125,000 lbs

Table 2-5 Red Line Weight Limits

A. Note: for Both Orange and Red Line, weight limit assumptions:

1. 5' 4" (1626 mm) clear side door opening

2. 12" (305 mm) knee room forward of seats

3. 155 lb/passenger

4. AW2 = 3 sq-ft/passenger (.28 sq-m)

5. AW3 = 1.5 sq-ft/passenger (.14 sq-m)

6. Flip seats raised

2.01.09. Weight Balance

A. The vehicles shall be designed to balance weight per powered axle, to the maximum extent possible.

1. Each truck under the Cab Car shall support 49% to 51% of the vehicle weight.

2. Each Non-Cab Car truck shall support 49.5% to 50.5% of the vehicle weight.

B. Each wheel load shall be 23%-27% of the total weight on the 4 wheels of each truck.

C. The maximum allowed lateral imbalance shall be 25,000 in-lbs (2,825 N-m).

2.01.10. Seating Layout

A. Longitudinal seating shall be provided. The minimum number of seats (including flip down seats) shall be as follows:

1. Orange Line – 44 seats per Cab Car and 50 seats per Non-Cab Car.

2. Red Line - 43 seats per Cab Car and 50 seats per Non-Cab Car.

2.01.11. Hour Meters

A. Major systems such as Propulsion, Auxiliary Inverter, Low Voltage Power Supply and HVAC units shall have hour meters incorporated into their data logging systems.

B. The hour meters shall be re-settable via a laptop Portable Test Unit (PTU) using appropriate access levels.

2.01.12. PTU Access Ports

A. All major subsystems shall be fitted with local access ports for PTU access. Ports shall be standardized throughout the vehicle such that a single cable design may be used for access. Industrial ports shall be provided, such as a D coded M12 connector. The access port shall have a self closing dust cover.

B. Other connector types may be proposed for approval by the Authority during the design review.

2.01.13. Car Keys

A. The Master Controller Transfer Switch Key shall be identical to that used on the #5 Blue Line. See appendix for details of the Transfer Switch Key.

B. All other locks on the vehicle, except locks specifically called out, shall open with the standard Authority Crew Key, MBTA Part No. 027-10-063, as used on existing cars. See appendix for details of the Crew Key.

C. 500 sets of keys shall be delivered by the Contractor with the first car.

1. Each set of keys shall include 1 Transfer Switch Key and 1 Crew Key.

2.02: PERFORMANCE

2.02.01. Load Weigh Compensation

A. The propulsion and braking systems shall use a load weigh compensation system to compensate for car loading between AW0 and AW3.

1. Acceleration curves shall be the same for car loadings from AW0 to at least AW2.

2. Braking rates shall be the same for car loadings AW0 to AW3.

B. The contractor shall propose a methodology of how the load weigh system reacts to fault conditions, however no failure of the load weigh system shall cause a service or emergency braking effort less than AW0 effort. [CDRL 02-25]

2.02.02. Acceleration

A. Performance of each Married Pair shall be verified by tests. Design calculations shall include train resistance as calculated by the modified Davis Formula for a 4 or 6-car train with new wheels:

B. A 4 or 6 car train-set shall accelerate at a constant rate of 2.75 mphps +/-5% (after jerk limited start) up to a tractive-effort base speed corner point of at least 16.3 mph +/- 0.2 mph under the following conditions:

1. Level tangent track

2. New wheels

3. Car weights from AW0 to at least AW2

4. Line Voltage = 600 VDC

5. Master Controller in Maximum Power position

6. ATP bypassed or showing an aspect of 25 mph or greater

C. Not used.

D. The overall efficiency of the propulsion system, including, line inductor, inverter traction motors and gear units, shall be 80% or greater at the point of maximum propulsion system line current draw.

E. The line current drawn by the propulsion system from the third rail shall not exceed 1080A for the Red Line or 1060A for the Orange Line.

F. Not used.

G. Neither the tractive effort base speed corner point nor the 2.75 mphps acceleration rate shall increase for line voltages above 600 volts.

H. For Line Voltage between 600 volts and 530 volts, and vehicle weights up to at least AW2, the acceleration rate and the traction effort corner point shall be maintained up to the current limits defined above. Where necessary, the tractive effort corner point may be cut back to meet the current limit.

I. Below 530 volts down to 400 volts, performance shall be reduced to lower propulsion system line current drawn from the Traction Power System and limit low line voltage shutdowns. The concept for reducing the propulsion line current draw under low line voltage conditions shall be reviewed and accepted by the Authority. Propulsion shall shut down at line voltage below 400 volts with hysteresis to prevent cycling.

J. With car weights up to AW2, line voltage of 600 volts, new wheels and no automatic speed regulation, a Married Pair shall have the following jerk limited performance (reference 2.02.04 Jerk Limits).

K. In ATP/ASR manual mode, for any given speed up to the signal aspect speed and for any given load weight up to AW2, tractive effort shall vary linearly with Master Controller position between Minimum Power and Maximum Power.

2.02.03. Dynamic (Electric) Brake

A. With a Married Pair loaded to any weight from AW0 to AW3 and the Master Controller in the full service brake position,:

1. The dynamic brake system (in rheostatic, regenerative or mixed mode) shall provide an instantaneous deceleration rate of 3.0 mphps, +/- 5%, from 42 mph down to 3 mph on level tangent track.

2. Friction/dynamic brakes shall be blended to compensate for low speed dynamic brake fade.

3. Not used.

4. Taper of the maximum AW3 dynamic braking effort shall also be allowed above approximately 42 mph. Friction brakes shall be blended to maintain 3.0 mphps brake rate up to 65 mph.

5. Not used.

6. The combination of dynamic and friction braking effort shall vary proportionally for Master Controller positions between Minimum Brake and Full Service Brake.

7. The Minimum Brake rate shall be 0.5 mphps, +/- 0.1 mphps

8. Dynamic brake rates shall be measured by the V/T method from the point of 90% of motor current build up to stop.

B. Regenerative braking shall be available to a receptive line at line voltages up to a software configurable limit which may be set as high as 800 VDC.

C. Regenerative braking shall be able to return to a fully receptive line, between 530 and 700 volts, no less than 72% of available kinetic energy, when braking from 42 mph (80.5 km/hr) down to 5 mph (8 km/hr) at a AW3 weight.

2.02.04. Jerk Limits

A. The jerk rate limit for all positive and negative changes in tractive effort shall be adjustable from 1 mphpsps to 3 mphpsps, with a tolerance of ± 10%. The jerk rate limit shall initially be set at 2 mphpsps.

2.02.05. Response Times.

A. The maximum dead time between a request by the Master Controller (or the ATP/ASR unit) for a change in acceleration or deceleration within the same mode and the beginning of a propulsion system jerk-limited response shall not exceed 150 milliseconds. The 150 millisecond response time shall include trainline delays to the last car.

B. The dead time between a request for a change in mode by the Master Controller (or the ATP/ASR unit) and the beginning of a jerk limited transition to the requested acceleration or braking effort by the propulsion system shall not exceed 300 milliseconds. The 300 millisecond response time shall include trainline delays to the last car.

C. The dead time between a request for application of brakes and the beginning of the buildup of brake pressure by the friction brake system when braking with friction brakes only shall not exceed 300 milliseconds.

2.02.06. Thermal Duty of the Propulsion System

A. Continuous Duty Operation

1. Maximum Continuous Duty

With an AW3 loading, maximum ambient temperature, maximum variation in wheel diameters and a line voltage between 530 to 700 volts, a 6 car train shall be able to operate continuously for the entire length of the Red or Orange Line. The 6-car train shall accelerate at the maximum rate up to maximum ATP controlled speeds and decelerate at maximum rate for station stops. Station stops shall be limited to 30 seconds, with 3 minutes layover at the terminal locations. Under these conditions, no part of the propulsion system shall exceed the manufacturer's recommended temperature limits for a 30 year life. Traction motor temperatures shall not exceed the temperature limits defined in T 10.05, Propulsion & Dynamic Braking Traction Motors. No inverter component shall exceed the continuous duty temperature requirements described in T 10, Propulsion & Dynamic Braking.

2. Degraded Continuous Duty

At AW3 average loading, with propulsion cut out on 16% of the trucks in the train, with worst case ambient temperatures, with maximum variation in wheel diameters and with line voltage between 530 and 700 volts, a 6-car train shall be able to run continuously in normal revenue service. Normal service shall include 30 second station stops and a 3 minute layover at terminal locations. Under these conditions, no traction motor or traction inverter component junction temperatures shall exceed the continuous duty temperature limits defined in T 10, Propulsion & Dynamic Braking, or trigger an over temperature shutdown.

B. Towing Operation

1. At AW3, with maximum ambient temperatures, with line voltages between 530 and 700 volts and with maximum variation in wheel diameters, a train, shall be able to tow a dead (no propulsion-no brakes) AW3 train of equal size between any two stations regardless of grade. Under these conditions no traction motors or traction inverter components shall exceed the towing duty temperature limits defined in T 10, Propulsion & Dynamic Braking, or trigger an over temperature shutdown.

2. At AW0, with the ambient temperature, wheel diameter and line voltage conditions defined above, a train shall be able to tow a dead AW0 train of equal length the entire length of the Red or Orange Line once. . During the towing, the train shall proceed under the command of the wayside signal system and shall proceed through stations at 10 mph. Under these conditions, no traction motors or traction inverter components shall exceed the towing duty temperature limits defined in T 10, Propulsion & Dynamic Braking, or trigger an over temperature shutdown.

C. Brake Resistor and Brake Chopper Thermal Capacity

1. With regeneration cut out and maximum ambient temperatures, an AW3 train shall be able to complete the Maximum Continuous Duty cycles described in the previous paragraphs, without exceeding temperature design limits, triggering an over temperature shutdown, or suffering any damage to the brake resistors, resistor mounting hardware or brake chopper components. Brake resistor temperatures shall not exceed the limits described in IEEE STD 16-2004, Table 5.

2. An AW3 Married Pair vehicle towing a dead AW3 Married Pair vehicle shall be able to move at 15 mph down the longest grade on the Red or Orange Line with regenerative braking cut out. This test shall not trigger an over temperature shutdown, nor damage/overheat the brake resistors, resistor mounting hardware or

brake chopper components. Brake resistor temperatures shall not exceed the limits described in IEEE STD 16-2004, Table 5.

2.02.07. Friction Braking

A. With any load weight up to AW3, using load weigh compensation, the service friction brake system alone shall have the capability of producing an average brake rate 2.75 mphps, starting from any speed up to 60mph.

B. Friction Brakes shall blend with dynamic brakes to produce the requested brake rate. If dynamic braking is unable to supply the requested brake rate or is unavailable, friction brakes shall make up the difference, up to maximum friction brake rate.

1. The tolerance on average friction full service brake rate shall be -10%, +20%.

2. The tolerance on instantaneous brake rate shall not exceed ± 20%.

3. Minimum Brake rate with friction brakes only shall be 0.5 mphps, ± 0.15 mphps.

C. Friction brakes shall automatically compensate for high speed dynamic brake taper, low speed dynamic brake fade and for loss of dynamic brakes, up to the limit defined above.

D. Brake rates shall be measured by the V/T method from the point brake cylinder pressure reaches 90% of the commanded value to the point at which the train stops.

E. The friction brake system shall have sufficient thermal capacity to allow cars to run in normal service operation for two complete roundtrips with the dynamic brake cut out. There shall be no loss of braking effort due to brake fade. During service operation with friction brakes only, no wheel damage or life reducing wheel temperatures shall occur. This requirement shall apply for all allowable wheel diameters.

F. The friction brake system shall have sufficient thermal capacity to allow cars to run in normal service operation for up to 2 days with 25% of the train's dynamic brake cut out. There shall be no loss of braking effort due to brake fade. During service operation with friction brakes only, no wheel damage or life reducing wheel temperatures shall occur. This requirement shall apply for all allowable wheel diameters.

G. The service friction brake system shall meet the jerk limit requirements defined for the propulsion system.

2.02.08. Emergency Brakes

A. Emergency brakes shall be friction only, with no electronic control of brake cylinder pressure other than possibly slide control modulation. (Whether slide control will be allowed in emergency brake shall depend on review of the slide control FMECA and braking test data. Provisions shall be made allowing or disabling slide control in emergency. See section T 12, Friction Brakes & Pneumatic System.)

B. Within 100 milliseconds of removal of energy from the Emergency Trainline, the traction inverter shall be shut down and its gates shall be blocked. The Traction Unit Line Contactor shall open.

C. Removal of energy from the Emergency Trainline shall cause the Emergency Magnetic Valve on every car to open, evacuating the Emergency Brake Pipe.

1. Brake cylinder pressures on all trucks in a train shall reach 90% of emergency brake pressure within 800 milliseconds of removal of energy from the magnet valves.

2. This time limit shall still be achieved with the failure of one Emergency Magnet Valve in a 6-car train.

D. The emergency brake system shall provide load weigh compensated braking without jerk limiting.

E. An emergency friction brake application shall result in an irretrievable braking to stop for any car loading from AW0 to AW3, at an average rate of 3.25 mphps +/- 20% starting from any speed up to 60 mph.

F. Emergency brake rates shall be calculated from the measured braking distance with the following formula:

$$Average\_Brake\_rate = \frac{speed\_at\_90\%\_brake\_cylinder\_pressure^2 \times K}{2 \times (Total\_Braking\_D - Calculated\_brake\_buildup\_D)}$$

Where:

1. Speed_at_90%_brake_cylinder_pressure is measured in miles per hour.

2. *K* is the conversion factor from mph to feet per second, 1.4667 fps/mph.

3. *Total_Braking_D* is the distance from the trip point to the stop point.

4. *Calculated_brake_buildup_D* is the distance traveled during brake buildup. This distance is calculated by trapezoidal integration of velocity over time during brake buildup.

G. For additional Emergency Brake requirements refer to T 12, Friction Brakes and Pneumatic System.

2.02.09. Parking Brakes

A. Parking Brakes shall hold an AW3 train with all Parking Brakes applied under wet rail conditions on a 6% grade indefinitely under all allowable wheel diameter and brake pad conditions.

2.02.10. Supply Voltage

A. The direct current third rail power system is supplied by 6 phase, 12 pulse silicon diode rectifiers providing a nominal voltage of 600 VDC.

B. All equipment on each car shall be self-protected from damage and improper operation due to:

1. High-voltage transients across the supply terminals of that equipment.

2. High-voltage transients impressed between supply terminals or between a supply terminal and the car body.

3. Long-term over-voltage and under-voltage conditions resulting from other equipment failure modes.

C. All traction and auxiliary system converters shall have sufficient filtering of line voltage power to:

1. Prevent damage to the equipment from line transients.

2. To limit conductive emissions to the third rail as specified in T 02.07, Electrical Interference.

D. The third rail system voltage will contain positive and negative high voltage transients due to faults and fault clearing, vehicle loads, regeneration from other Authority trains, lightning, and other transient generators. It shall be the responsibility of the Contractor to ensure that all equipment provided is protected from such transients. At a minimum, the Contractor shall ensure that all equipment is protected from and or is immune to all transients described in the latest version of IEC 61287-1.

E. If definition of maximum high voltage transients is needed for system design, the Contractor shall conduct transient voltage studies as appropriate with the cooperation of the Authority. Any data obtained in the course of these studies shall be the property of the Authority.

F. All vehicle equipment shall be capable of operation with line voltages between 400 VDC and 800 VDC without damage.

2.02.11. Auxiliary Power Inverters (API)

A. All auxiliary rotating equipment, except electric door operators and windshield wipers, shall be powered by balanced 230VAC 3 phase 60 cycle power provided by an Auxiliary Power Inverter.

B. 230 Volt AC power shall ramp up with a constant voltage-frequency ratio and lock into a 60 Hz frequency ±2 Hz.

C. The total harmonic distortion of the API voltage output shall be less than 5%.

D. API harmonics shall be taken into account in sizing motors attached to the API.

E. Droop on worst case motor start up shall be less than 20%.

F. The API shall be capable of functioning without damage or lockout under extremely intermittent power, as may be caused by third rail gaps or ice on the third rail.

2.02.12. Low Voltage Power Systems (LVPS)

A. The Low Voltage Power Supply with secondary battery shall supply power to all low voltage DC equipment attached to the Low Voltage Distribution Network (LVDN).

B. The LVPS shall be capable of functioning without damage or locking out under extremely intermittent power as may be caused by third rail gaps or ice on the third rail.

C. The Low Voltage Distribution Network shall supply each piece of low voltage equipment with power conforming to IEEE Std. 1476-2000, IEEE Standard for Passenger Train Auxiliary Power Systems Interfaces, as follows:

1. Maximum Voltage 42 VDC

2. Nominal LVPS Voltage 37.5 VDC

3. Minimum Voltage at Load 23 VDC

D. The LVPS and equipment attached to the LVDN shall meet the voltage fluctuation and over voltage limits and immunity required by IEEE Std. 1476-2000, sections 4.4.3.4 and 4.4.3.5.

E. All equipment attached to the LVDN shall operate reliably, within the voltage range and power quality specified above.

F. All equipment attached to the LVDN shall be immune to damage from continuous application of voltage between zero and the minimum LVDN voltage specified above and to application of reverse polarity voltage.

G. All equipment attached to the LVDN shall be protected against electrostatic discharge and transients in accordance with IEEE Std. 16-2004 Sections 4.3.1.4 and 4.3.1.5.

2.02.13. Thermal and Acoustical Insulation

A. An approved type of thermal insulation shall be installed throughout the vehicle to attain the car conductivity requirements below. Closed carshell sections shall be filled with insulation during shell assembly, as required. Contractors shall determine the required type and thickness of insulation to comply with the overall Heat Transfer (UA) value of the car = 800 BTU/Hr-°F. Calculations of the UA value shall be submitted for review and approval by the Authority. [CDRL 02-03]

B. Insulation shall include a vapor barrier and be firmly affixed to all vehicle surfaces utilizing stainless steel weld pins, or an equivalent mechanical fastening technique.

C. Insulation shall be applied to all air duct surfaces. Sweating shall not occur on any interior or exterior surface under any temperature or humidity level.

D. An approved acoustical insulation shall be applied to the underframe and subfloor, as well as sidewalls, ceiling and end walls, as required to meet the noise and vibration requirements listed below.

2.02.14. Noise, Shock and Vibration

A. Overall noise levels shall be measured in dB on the A scale (dBA) with slow meter response setting for stationary vehicle measurements, and fast meter response for moving vehicle measurements. Noise shall be measured in accordance with ANSI S1.4

1. With the vehicle stationary and all equipment running in revenue service conditions, the interior noise level shall not exceed 72 dBA.

2. At vehicle speeds up to 60 mph on above ground track, the maximum internal noise level shall not exceed 78 dBA.

3. In the subway sections of the right of way, the maximum internal noise level shall not exceed those of existing Red Line #3 vehicles.

4. Noise external to a stationary vehicle shall not exceed 70 dBA at a distance of 50 feet.

5. Noise external to the vehicle, when measured 50 feet from a train traveling at 60 mph and braking, shall not exceed 82 dBA.

2.02.15. Shock and Vibration

A. In vehicles traveling at speeds from 0 to 60 mph, vibration levels shall be at or below levels required to successfully pass the Ride Quality Test conducted per ISO 2631 (1997 edition).

B. Carbody mounted equipment, including mounting brackets, shall be designed to withstand shock loads of 3g lateral, 3g vertical, and 5g longitudinal. Shock duration shall be 4-10 ms. Shock frequency shall be determined after consultation between the Contractor and the Authority.

C. All truck frame-mounted equipment shall be designed to withstand vibration of ±2 g in the frequency range of 1 - 100 Hz in all directions, and shocks in each direction with a duration of 4-10 ms of vertical: ± 30 g, lateral: ± 15 g, and longitudinal: ± 10 g.

D. All truck wheelset-mounted equipment shall be designed to withstand vibration in all directions of ±10 g in the frequency range of 0 - 100 Hz , and shocks in each direction with a duration of .5-2 ms of vertical: ± 100 g, lateral: ± 100 g, and longitudinal: ± 100 g.

2.02.16. Ride Quality

A. The Contractor shall use the design data for new vehicles to predict the lateral and vertical ride quality per ISO 2631-1, 1997 05-01 (0.5 - 80 Hz), and compare this to a similar simulation of the existing vehicles using data provided by the Authority. The Contractor shall be responsible for estimating or measuring all data not available in the Authority records or any data considered critical to the design. The new vehicle suspension design shall be adjusted as necessary to achieve improved ride quality.

B. The vibration total value of acceleration shall be weighted r.m.s. and calculated as follows:

$a_v = (k_x^2 a^2_{wx} + k_y^2 a^2_{wy} + k_z^2 a^2_{wz} + k_x^2 a^2_{wx})^{1/2}$

where a_{wx},a_{wy} and a_{wz} are the weighted r.m.s. accelerations and k_x, k_y and k_z are multiplying factors.

a_v is the vibration total value and shall be provided for ride comfort.

C. The actual Ride Quality shall be measured and evaluated as described in ISO 2631 (2003). Authority acceptance of the results shall require a ride quality equal to or better than the results obtained on the new Blue Line cars on similar track conditions.

1. Ride Quality shall be measured for all frequency bands with the 1/3 octave band method.

D. Ride Quality Test Plan shall be submitted for Authority review and Approval. [CDRL 02-04]

E. Ride Quality Test Report Shall be prepared and submitted for approval by the Authority. [CDRL 02-05]

2.03: RELIABILITY

2.03.01. General

A. The Contractor shall provide a vehicle which meets the reliability requirements of this sub-section under the environmental and operating conditions described in this specification.

2.03.02. Service Reliability

A. The Contractor shall supply a fleet of vehicles that shall meet the following service reliability:

1. The overall in-service reliability of the vehicle shall be greater than 90,000 miles (144,840 km), Mean Distance Between Failure (MDBF), where MDBF is defined as:

$$MDBF = \frac{Total\_miles\_accumulated\_by\_all\_cars\_in\_the\_fleet\_for\_the\_period}{service\_failures\_for\_the\_period}$$

2. Service failures are any failures that cause more than a 4 minute delay of the train or an unscheduled removal of a vehicle from service.

    a. Accidents, operator errors, failures caused by failure to perform approved maintenance procedures, and failures caused by environmental conditions exceeding those defined in this section shall not be included.

    b. System failures for which no trouble can be found (NTF) shall be counted as failures after the third NTF- failure of the same system/component on the same car until the cause can be determined and corrected.

B. Not used.

2.03.03. System and Component Reliability

A. The vehicle provided by the Contractor shall also meet or exceed the following system or component reliability requirements:

System	**Mean Distance Between Component Failures (MDBCF)**
Propulsion	100,000 miles (160,930 km)
Friction Brakes and Pneumatic System	80,000 miles (128,750 km)
Auxiliary Power System (including both LVPS and Auxiliary Power Inverter)	150,000 miles (241400 km)
Lighting (not including lamps)	1,000,000 miles (1,609,300 km)
HVAC System	100,000 miles (160,930 km)
Doors and Door Controls	80,000 miles (128,750 km)
Cab Equipment and Controls (Master Controller, Operators console control and indications, cab heater, etc.)	250,000 miles (402,340 km)
Communications (including signs, but not CCTV cameras and recorders)	50,000 miles (80,467 km)
Trainlines and Networks (includes coupler pins)	300,000 miles (482,800 km)
ATP/ASR	300,000 miles (482,800 km)
Vehicle Monitoring System including Vehicle Monitoring Display	400,000 miles (643,740 km)
Trucks	350,000 miles (563,270 km)
Coupler and Draft Gear (mechanical parts)	1,000,000 miles (1,609,300 km)

System	Mean Distance Between Component Failures (MDBCF)
Whole Car	11,150 miles (17,944 km)

Table 2-7 Component Reliability Targets

Note - CCTV system is not included in vehicle reliability calculations.

1. MDBCF shall be defined as:

$$MDBCF = \frac{Total\_miles\_accumulated\_by\_all\_cars\_in\_the\_fleet\_for\_the\_period}{component\_or\_system\_failures\_for\_the\_period}$$

2. Component or system failures shall be defined as any failures that require replacement or adjustment of any component to return the system to normal operation, whether the failures occur in service or not.

3. Failures discovered during inspection shall be counted as component/system failures.

4. Software failures that require the Authority's operating personnel to "re-boot" the system or take other actions to return the system to normal operation shall be counted as component failures, even if no action is required by maintenance personnel.

5. System failures for which no trouble can be found (NTF) shall be counted as failures after the third NTF failure of the same system on the same car.

6. The replacement of consumable items such as filters, lamps, brake shoes, etc, shall not be considered as a component failure, unless the consumables fail to meet their specified life.

7. Failures caused by accidents, vandalism, operator or maintenance error shall not be counted.

B. Failures caused by improper operation, testing or maintenance due to faulty Contractor supplied documentation shall be counted as component/system failures.

C. The failures for items not listed in the table above shall not constitute more than 5% of all failures. CCTV equipment failures shall be tracked separately and not included in Whole Car MDBCF.

D. The breakdown of some systems for accounting purposes may change based on how the systems are divided among suppliers, but the overall system and car targets must still be met.

E. CCTV system cameras shall have a Mean Time Between Failures (MTBF) > 60,000 hours.

F. CCTV system Network Video Recorder shall have a MTBF > 200,000 hours, excluding the hard drive.

2.03.04. Availability

A. Vehicle reliability and vehicle maintenance requirements shall be such that fleet availability shall exceed 90%, where availability is defined as:

$$\text{Availabilty} = \frac{\text{Available\_cars}}{\text{Total Number of cars in the fleet}}$$

B. Available cars are all cars which are not removed from service for scheduled or unscheduled maintenance or repairs. When one car of a married pair requires repairs, both cars shall be considered unavailable.

2.03.05. Reliability Analysis

A. The Contractor shall submit to the Authority for review and approval a reliability prediction summary report for all car systems listed in T 02.03.03 and for the car as a whole, demonstrating that the specified MDBF and MDBCF requirements shall be achievable. [CDRL 02-06]

B. The report shall be submitted as part of Preliminary Design Review. The reliability prediction for electronic systems shall use MIL HDBK 217F parts count method and part stress method for the ground mobile environment. For piece parts not contained in MIL-HDBK 217, certified field failure data covering a period or distance ten times the claimed MTBF or MDBCF shall be used. IITRI/RAC Document NPRD-95 shall be used for non-electronic parts. Use of other prediction standards may be proposed for Authority review and approval, provided that the standards account for the environmental stress experienced in the Authority's application. Wherever possible, the reliability prediction shall be supplemented by actual field data for the system or subsystem.

C. The Reliability Prediction Summary Report shall be maintained and updated through the entire design, testing, manufacture, delivery and warranty periods. The Contractor shall submit the updates to the report to the Authority for review and acceptance at the on a monthly basis as the project progresses. Updates shall report on design or manufacturing changes, or problems that may affect vehicle reliability.

2.03.06. Reliability Program Plan

A. The purpose of the Reliability Program is to correct reliability problems as early as possible in the program, to ensure the highest possible reliability and to minimize required field modifications.

B. Within 90 days of Notice to Proceed (NTP), the Contractor shall submit a Reliability Program Plan (RPP) for the Authority's review and approval. [CDRL 02-07]

1. The RPP shall address the organization and personnel responsible for reliability control and management.

2. The RPP shall include at least the following elements of the MIL-STD 785B:

   a. Use of reliability prediction, allocation, and modeling to identify problem areas and to guide design and manufacturing efforts.

   b. Monitoring of the work of subcontractors and suppliers

   c. Controls for ensuring subcontractor compliance with the methods of the reliability program.

   d. Program Review

   e. Failure Reporting, Analysis and Corrective Action System (FRACAS) and the organization for failure review and management of analysis and corrective action.

C. The Contractor shall have its Reliability Engineer assigned to this procurement program during the execution of the Contract. The Reliability Engineer shall have sufficient authority within the Contractor's organization to effectively plan and implement the reliability program and assure achievement of the quantitative and qualitative reliability requirements. The Contractor shall submit the qualifications of the Reliability Engineer to the Authority for review and approval. [CDRL 02-08]

D. The Contractor shall, in accordance with MIL-STD 785B, establish a Failure Review Board (FRB). In addition to the Contractor's representative and engineers, the FRB shall include the Authority and its technical representatives. The FRB shall review all failures, determine which are relevant and determine the need and depth of failure analyses and corrective action. The Authority shall have the power to make binding decisions about the need and depth of failure analyses for any item reviewed. The Failure Review Board shall be established 60 days prior to the commencement of pilot car testing.

E. The FRACAS and FRB shall continue to function until the close of the warranty period for the last car.

2.03.07. Pilot Train Reliability Test

A. Before the Married Pairs in the Pilot Train are accepted by the Authority, the vehicles must successfully complete a Pilot Train Reliability Test. During this test, the Pilot Train must successfully operate for 40 consecutive hours on the line for which it is designed, stopping and cycling the doors at every station, without any failures of any system. During the test, various systems such as windshield wipers, door operators, etc shall be randomly or continuously tested. All systems must be fully operational during the test. [CDRL 02-09]

1. During the Qualification Test period and the Pilot Train Reliability Test period, all failure trends shall be investigated and analyzed to determine the root cause.

The results shall be reported to the FRB. Based on these investigations, the Contractor shall submit for Authority approval, any necessary design and manufacturing modifications to improve fleet and system reliability.

2.03.08. Fleet Reliability Demonstration Test

A. The Fleet Reliability Demonstration Test shall commence after the 30th car for each fleet is accepted. From this point on, all Married Pairs that have been accepted and running in Revenue Service for 2 months or more shall be enrolled in the test. This test shall show that the vehicles and their systems meet the quantitative service and component reliability and availability targets defined in this section. All Married Pairs shall remain in the test until its successful completion.

B. The Contractor shall present, for Authority approval, its plan for FRACAS implementation during the Fleet Reliability Demonstration, including record keeping, failure investigation procedures and corrective action procedures. [CDRL 02-10]

C. The Failure Review Board shall keep records of all failures. All failure trends shall be investigated to determine the root cause.

D. If the FRB determines that a problem or defect is inherent (failures of the same component in the same application exceeds a failure rate of five (5) percent during any period of twelve (12) consecutive months based on the average number of such components in service during such twelve month period) throughout the fleet or is inherent in the design, the Contractor shall be responsible for correcting the problem by implementing a design modification. Repeat or random failures which continue to prevent any system or component from meeting its reliability targets shall be thoroughly investigated by the Contractor. The Contractor and its suppliers shall propose to the Authority for review and approval, design, manufacturing or repair changes that will improve reliability to specified levels. Approved changes shall be implemented fleet wide and the reliability results tracked. Where necessary, the warranty period shall be extended to cover the implementation and verification of the effectiveness all design modifications required to meet reliability goals.

E. The Contractor shall meet the following reliability milestones during the Reliability Demonstration:

1. After 6 months [CDRL 02-11]:

   a. MDBF ≥ 35% of the service reliability target.

   b. MDBCF ≥ 35% of the component reliability target for each system and for the vehicle.

2. After 12 months [CDRL 02-1]:

a. MDBF ≥ 60% of the service reliability target, based on a rolling 3 month average.

b. MDBCF ≥ 60% of the component reliability target for each system and for the vehicle, based on rolling 3 month average.

c. Availability ≥ 70%, measured daily at 4:00 pm.

3. After 2 years:

a. MDBF ≥ 100% of the service reliability target based on a 6 month rolling average.

b. MDBCF ≥ 100% of the component reliability target for each system and for the vehicle, based on a 6 month rolling average.

c. Availability ≥ 90% measured daily at 4:00 pm.

F. Successful completion of the Reliability Demonstration shall be defined as a 6 month cumulative average where all MDBF and MDBCF and availability targets are met or exceeded, regardless of vehicle warranty completion.[CDRL 02-13]

2.04: MAINTAINABILITY

2.04.01. General

A. The Contractor shall provide a fleet of vehicles that shall require a minimum of preventive and corrective maintenance time.

2.04.02. Maintenance Schedule and Mean Time To Repair (MTTR) Estimates

A. A Preventative Maintenance Schedule shall be submitted for review and Approval by the Authority. [CDRL 02-14]

B. The Contractor shall design a vehicle and subsystems for which preventive maintenance tasks can be scheduled in multiples of 90 days to conform to the Authority's existing preventive maintenance cycle. Deviations from this requirement shall require approval of the Authority prior to Final Design Review.

C. Scheduled 90 Day maintenance shall require less than 12 man hours per car.

D. The Contractor shall provide, for Authority review and approval, estimates of the Mean Time To Repair for key preventive and corrective maintenance tasks for all major subsystems. The estimates shall be submitted 60 days prior to Final Design Review. [CDRL 02-15]

2.04.03. Maintainable Design

A. Maintainability targets shall be met through:

1. Use of digital technology to reduce calibration, adjustment and other corrective and preventive maintenance requirements.

2. Vehicle monitoring and diagnostic systems and test equipment designed to detect and isolate problems to the Line Replaceable Unit. Refer to T 16, Vehicle Monitoring System and T 22, Systems Assurance, for detailed requirements.

3. Hinged covers, slide out printed circuit boards, quick-disconnects, captive fasteners and other design options to facilitate quick removal and replacement of parts.

4. Easily accessible and easily replaceable filters.

5. Design for clearances and easy access to all replaceable or repairable parts.

6. Easily accessible and clearly marked terminal boards and troubleshooting test points.

B. In general, all replaceable or repairable items shall be mounted so that other items do not need to be removed to gain access. Where this is not possible, more frequently maintained, adjusted or replaced items shall be located in front of less frequently maintained, adjusted or replaced items.

C. Mockups and 3-D visualization shall be used to ensure clearances and accessibility.

2.04.04. Maintainability Demonstration

A. The Contractor shall perform a maintainability demonstration on the vehicles of the Pilot Train. The contractor shall demonstrate the repair time for maintained items for each system per the instructions of the Running Maintenance Manual and the Heavy Maintenance Manual. [CDRL 02-16]

2.05: PASSENGER ACCESSIBILITY

A. MBTA is committed to procuring vehicles that allow full accessibility. The following provisions shall be included in the design:

1. Compliance with the applicable Americans with Disabilities Act (ADA) requirements

2. 32 inch wide clearance per open side door leaf

3. Between car barriers

4. 30 inch wide emergency egress end doors and folding evacuation chair

5. Visual and audible door open and door closing warnings

6. Synchronized automatic audio and visual station announcements

7. Passenger Emergency Intercoms located near wheelchair locations at accessible heights

B. Gap Fillers (See T 6.02.10 Gap Mitigation Devices / Bridging Mechanism)

C. It is the Contractor's responsibility to assure that the vehicles meet or exceed all current applicable requirements of the ADA.

2.06: SAFETY

2.06.01. Safety Certification

A. The Contractor shall provide a quantifiable comprehensive safety certification of the design of the vehicle prior to the vehicle being conditionally accepted by the Authority. This safety Certification shall ensure that all known hazards have mitigated to a risk and Mean Time Between Hazardous Events (MTBHE) are acceptable to the Authority. This certification shall be update as required if modification to the design could impact safety [CDRL-02-21]

B. The Contractor shall develop a Safety Certification Plan (SCP) which shall detail how safety certifications of each sub-system and the vehicle as a whole will be achieved. The plan shall describe what process will be followed during the entire procurement phase to identify, track, and maintain these certificates. In addition, the plan shall be reviewed and approved by MBTA Safety. [CDRL-02-26]

C. As supporting documentation to the Safety Certification the contractor shall provide the following submittals

1. System Safety Program Plan

   a. The Contractor shall develop a System Safety Program Plan (SSPP) which shall detail how all hazards related to the vehicle will be identified categorized, mitigated, tracked, and closed. [CDRL 02-17]

2. Hazard List

   a. The Contractor shall within 60 of NTP provide an initial Hazard list. This hazard list shall identify all potential hazards associated with the vehicle including those caused by, mechanical failures, electrical/electronic component failures, software errors or defects, environmental impacts, human error, maintenance, and operational conditions. [CDRL-02-22]

3. Preliminary Hazards Analysis (PHA)

   a. Based on the approved Hazard list the Contractor shall provide a Preliminary Hazard Analysis which defines the potential cause of the hazards, the probability of the hazard, the severity of the hazards, potential or proposed mitigation and the residual probability and severity. The PHA shall be submitted prior any Preliminary Design Reviews [CDRL-02-23]

4. Hazard Tracking Log (HTL)

a. Based on the approved PHA the contractor shall develop a Hazard Tracking Log. This HTL shall track the status of all supporting documentation for each of the hazards. All hazards in the Hazard Tracking Log must be closed for Safety Certification to be closed. The HTL shall be submitted prior to any Final Design Reviews and be updated monthly until approved. [CDRL-02-24]

5. Failure Modes, Criticality Effects Analysis (FMECA)

a. The Contractor shall provide a comprehensive FMECA(s) for all components on the vehicle. For the purpose of this paragraph components shall be defined as hardware, electronic/electronic components and software at a minimum it shall be to the level of an assembly (e.g. relay, contactor, actuator, valve, switch etc) but many be to sub assembly level if required by the authority in order to more clearly define the hazard. The FMECA shall also identify if the failure is annunciated. In the event that the failure is not annunciated the analysis shall be extended to include subsequent failures until the subsequent failure is annunciated.

6. Fault Tree Analysis (FTA).

a. The Contractor shall provide a quantifiable Fault Tree Analysis for all Category/Severity one and two hazards. These fault trees analyses shall be fully integrated across sub system such that if events span multiple sub systems the top event vehicle level hazard reflects all sub system events.

7. Subsystem Hazard Analysis (SSHA)

a. The Contractor shall submit a subsystem hazard analysis for each vehicle subsystem. These subsystems safety analysis shall include subsystem Hazard Tracking log, FMECA, and FTA. The documents shall be submitted as part of the PDR and FDR submittals.

D. Probability. Severity, and Risk

1. For the purpose of this section the Contractor shall utilize the following definition for hazard severity category, hazard frequency levels and acceptable risk

Hazard Severity Categories		
Severity	Category	Definitions
Catastrophic	I	Death, permanent total disability.
Critical	II	Permanent partial disability, severe injury or occupational illness that may result in hospitalization of at least three personnel.
Marginal	III	Injury or occupational illness resulting in loss of 1-2 work days.

Negligible	IV	Injury or illness not resulting in lost work days.

Hazard Frequency Levels			
	Frequency	Specific Individual item (Quantitative assessment)	Fleet Assessment (Qualitative assessment)
Frequent	A	MTBHE is less than $1E10^3$	Continuously experienced throughout system life.
Probable	B	MTBHE is less than $1E10^5$ but greater than $1E10^3$	Will occur frequently throughout the life of the system.
Occasional	C	MTBHE is less than $1E10^7$ but greater than $1E10^5$	Will occur several times throughout life of the system.
Remote	D	MTBHE is less than $1E10^9$ but greater than $1E10^7$	Unlikely but can be reasonably expected to occur.
Improbable	E	MTBHE is greater than $1E10^9$	Unlikely to occur in the system life, but possible.

Safety Risk Index Matrix				
	Catastrophic (I)	Critical (II)	Marginal (III)	Negligible (IV)
Frequent (A)	UN	UN	UD	AR
Probable (B)	UN	UN	UD	AC
Occasional (C)	UN	UD	AR	AC
Remote (D)	UD	AR	AC	AC
Improbable (E)	AR	AC	AC	AC

Note: UN – Unacceptable UD – Undesirable AR – Acceptable with Review from MBTA AC – Acceptable

2. For individual component failures rates used in the safety analysis the Contractor shall utilize published failure rates for ground mobile equipment such as MIL-

HDBK-217F. Use of field data may be used if approved by the Authority.

3. For software failure probability rates used in the safety analysis it shall be assumed that all software has a Safety Integrity Level (SIL) of zero as defined by EN-50128. For common mode failure of comingled or redundant software a BETA or common mode failure rate of one shall be assigned. Alternatively if the Contractor can provide independent certification (e.g. TÜV certification) for a higher SIL level this may be used if approved by the Authority.

4. Unless it is shown otherwise though daily test or preventative maintenance inspection the “Time at Risk” for all failures probabilities shall be design life of the vehicle. All time at risks shall be approved by the Authority.

E. At a minimum, the Automatic Train Protection System, emergency brake application, emergency power removal, door opening , door/propulsion interlock and no motion detection shall be required to meet requirements for of Category I hazards for elimination of hazard or reduction of risk to an acceptable level.

F. Emergency brake control shall be fail-safe.

1. No detectable single point failure in the friction brake system, or series of common-mode or common-cause failures added to any combination of undetected failures, can result in the availability of less than 75 percent of emergency braking effort in a train.

G. In addition to the general safety design requirements of MIL-STD-882C, the following guidelines shall be followed:

1. The Contractor shall utilize only components with proven high reliability in the rail transit environment.

2. All devices not guaranteed fail-safe shall be assumed capable of failing in permissive modes.

3. All safety sensitive systems shall be designed on the closed circuit principle

4. Control of Propulsion and Braking shall be by two independent signals that must agree.

5. All safety circuits not wholly within an enclosure shall be of a double-wire, double-break design.

6. Loss of signal in systems controlled by variable level signals shall result in the most restrictive command.

7. No combination of wires or components becoming grounded shall cause any safety system to change to a less restrictive condition.

8. Electronic equipment, cables, and wiring shall be designed with sufficient interference immunity to guarantee safe operation under all possible environmental conditions.

9. Wires for safety critical trainline functions shall not be located at the bottom pins of cable connectors mounted in areas where water incursion may occur.

10. The location of pins and wires of safety critical circuits in connectors shall be designed to minimize the possibility of unsafe conditions resulting from shorts to adjacent pins or wires.

11. Systems that rely on structural integrity for safety shall have sufficient safety factors such that failures are not possible within the life of the vehicle under all possible conditions.

12. Safety critical components subject to wear shall not wear to permissive states within a period less than three times the overhaul period under the worst-case combination of duty cycle, environment, and all other influences. Such devices shall be clearly indicated as SAFETY CRITICAL in the maintenance manuals.

13. No mechanical lock or catch used as a safety critical device shall require electrical or pneumatic energy to remain locked.

2.06.02. Fire Safety

A. Fire safety shall be achieved through adherence to the following requirements:

B. All non-metallic components used on the vehicle shall be smoke, flame, and toxicity tested to NFPA 130, 49 CFR part 238, and BSS 7239. Maximum smoke developed, maximum flame spread indices, and toxicity emission limits shall be detailed in the specification. Waivers may be requested for items with minimal combustible content, such as the natural rubber seals on brake valves.

C. All heat sources on the vehicle shall be protected with redundant levels of protection so that circuits are open before unsafe temperatures exist.

D. Smoke detectors shall be located in each fresh/return air mixing plenum and supply duct. Automatic dampers shall prevent external smoke from entering the vehicle.

E. Protection from smoke and fire originating under the vehicle floor shall be proven through successful completion of a 30 minute floor fire test in accordance with ASTM E-119, NFPA 130, and 49 CFR, part 238.

F. Emergency egress shall be provided through vehicle end doors.

G. Two fire extinguishers shall be located in each car.

H. Passenger emergency brake actuators shall be located on both ends of the car and also unlock/open the adjacent cab door for access to the vehicle end door.

I. A manual door release on each passenger compartment side door and end door shall be provided.

2.06.03. Blast-Worthiness

A. As the criteria for blast-worthiness becomes more definitive, the MBTA would like to include a discussion of available options and their feasibility during the first design reviews of the interior general arrangement.

B. The intent is to minimize injuries caused by objects inside the vehicle, such as interior panels, windscreens, or lighting lenses, that become lose and are being accelerated through the vehicle by a blast.

C. Injuries to passengers at a station platform shall also be minimized to the greatest extent possible when a blast occurs on the railcar.

D. Design characteristics could include such features as window treatment, panel retention, and sacrificial pressure relief vents. The Contractor shall keep the MBTA aware of any cut-in deadlines for such design improvements.

E. Commercial impacts and potential change orders will be discussed should the MBTA desire the implementation of such changes.

2.07: ELECTRICAL INTERFERENCE

2.07.01. Electromagnetic Compatibility Plan

A. Prior to the Preliminary Design Review (PDR), the Contractor shall submit for review and approval an Electromagnetic Compatibility Plan (EMC Plan), [CDRL 02-18].

B. The EMC Plan shall include the Contractor's analysis of interference sources and receivers as outlined in APTA standard SS-E-10-98 Section 5.4

1. The Contractors EMC Plan shall ensure that the vehicle and its subsystems shall not interfere with wayside systems or be susceptible to emissions from wayside systems or existing vehicles under all operating conditions.

2. The emissions and susceptibility of onboard equipment shall meet the requirements of EN50155. The limits for RF emissions and susceptibility shall be extended to six gigahertz to be compatible with new technologies as approved by the Authority.

C. It shall be the responsibility of the Contractor to prevent interference between any subsystem or signal and any other subsystem or signal on the vehicle or train.

D. No vehicle system or subsystem shall be susceptible to the transmissions of an MBTA hand held radio or any cell phone held 18 inches from any enclosure or cable.

E. No vehicle system or subsystem shall interfere with the operation of any MBTA radio or any cell phone held anywhere on the car or adjacent to the vehicle under any mode of operation.

F. No Vehicle or subsystem may interfere with public safety frequency bands. Use of transmitters in those bands shall be approved by the Authority.

G. It shall be the responsibility of the Contractor to ensure that the neither the vehicle nor its communications systems interfere with systems of neighbors of the Authority's right of way along the Red and Orange lines. It shall also be the responsibility of the Contractor to ensure that the vehicle and its communications systems shall be immune to emissions and transmissions from neighbors of the Authority's right of way.

H. The EMC Plan shall also include the Contractor's plans to mitigate conductive, inductive and radiated interference by means of but not limited to:

1. Selection of signal levels to maintain signal to noise ratio at least 6 db above interference levels

2. Frequency selection for transmitters

3. Filtering

4. Inverter pulse patterns

5. Location and orientation and design of potential emission sources so as to minimize interference (e.g. Brake Resistors, Routing of Motor Leads etc.)

6. Proper shielding and termination

7. Cable routing and use of separate conduits and cables to reduce cross talk and interference from power cables as outlined in IEEE STD 16-2004. Section 4.8.2.1

8. Suppression of spikes caused by inductive loads

I. The Authority's acceptance of the EMC Plan does not relieve the Contractor of the responsibility to meet the requirements paragraphs A through H above.

2.07.02. Whole Train to Wayside Emission Limits

A. The Contractor shall have responsibility to verify limits for conductive, inductive and radiated emissions such that wayside and carborne signal equipment, will not be affected by vehicle or train emissions. The limits shall be set at least 6 db below measured interference levels. The inductive and conductive emissions limits shall be determined by tests with UMTA Suggested Procedures as a recommended starting point. The tests shall be performed within 90 days of Notice to Proceed (NTP). The test results and any modified limits shall be submitted to the Authority for review and approval [CDRL 02-19]. Tests at minimum shall measure:

1. Wayside voltage sensitivity of track circuit receivers for each frequency as seen from the tracks, with receiver amplifiers set at maximum gain.

2. Impedance of track circuit "WeeZ" bonds, as seen from the tracks.

3. Lowest substation impedance, as seen from the tracks.

4. 60 Hz voltage emissions from at least 2 substations on each line.

B. Conductive Emissions Limits

1. Worst case conductive emissions into the third rail shall be calculated by in phase paralleling of Norton equivalent currents and filter impedances of all the emission sources on all cars in an 6-car consist. Statistical methods shall not be used.

2. The MBTA uses Alstom audio frequency and power frequency track circuits on the Red and Orange Lines.

3. The following train detection frequencies are used on the Orange Line: 2970 Hz, 3330 Hz, 3510 Hz 3690 Hz, 3870 Hz, 4230 Hz, 4410 Hz and 4950 Hz.

4. The Orange Line uses 990 Hz for cab signal. The system is designed on the assumption that trains will detect any coded signal above 200 milliamps rms. The nuisance interference level for steady carriers is slightly lower. Due to wayside signal equipment limitations, it is not possible to reduce train pickup sensitivity.

5. The Red Line uses the following frequencies for train detection: 1300 Hz, 1950 Hz, 2580 Hz, 3060 Hz and 6950 Hz.

6. Alstom 60 Hz and 100 Hz B2 vane relays are used in interlockings and yards.

7. The Red Line uses 4550 Hz and 5525 Hz carriers for cab signals. Existing trains recognize coded signals above 130 milliamps rms.

8. Calculated limits based on equipment parameters from the signal manufacturer’s lab tests are provided below. These limits are provided for proposal purposes only. Field values may be higher or lower and must be verified by field testing before design may proceed.

Frequency	Single car limit (Note 1)	Worst case 6-car train limit (Note 2)	Substation plus track inductance at measurement point
58-62 Hz	490 ma	2.0 A.	150 uh
98-102 Hz	490ma	2.0 A.	150 uh
900-1100 Hz	50 ma	200 ma	150 uh
1200-1400Hz	42 ma	165 ma	150 uh
1800-2100 Hz	32 ma	125 ma	150 uh
2400-2700 Hz	28 ma	105 ma	150 uh
2850-4000 Hz	23 ma	90 ma	150 uh
4000-5200 Hz	21 ma	80 ma	150 uh
5200-5800 Hz	30 ma	130 ma	150 uh
6600-7100 Hz	10 ma	45 ma	150 uh

Table 2-8 Train to Wayside Conductive Emissions Limits

Note 1: Single car limits may vary according to filter impedances.
Note 2: The Contractor shall in all cases meet the worst case 6-car limits.

9. In addition to the limits in Table 2-8, conductive emissions shall not exceed 50 mA per car between 1100 Hz and 6600 Hz.

10. Conductive emissions shall be measured with "Conductive Interference in Rapid Transit Signaling Systems, Volume II: Suggested Test Procedures", UMTA-MA-06-0153-85-6, Method RT/CE02A as a reference point. Modifications shall be made to the test procedure to account for improvements in test equipment since the standard was published. Particular attention shall be paid to the following points:

    a. The substation or traction power source impedance must be measured at the point of test.

    b. The values of line filter elements for the equipment under test must be measured.

    c. The total train emissions shall be calculated from tests capturing worst case single car/single inverter emissions during power, braking or transitions.

    d. A smaller number of tests shall be run to verify that there are no unforeseen resonances or emissions instability with 4 or 6-car trains.

    e. Transients due to third rail conditions shall not be considered violations of emissions limits.

    f. Emissions spikes due to inverter mode change, etc, lasting less than 0.5 seconds shall not be considered violations of emissions limits.

    g. The FFT sampling windows shall be sufficiently small so as not to attenuate the measurement of emissions sweeping through frequencies as the train accelerates or decelerates.

11. In addition to the above emissions requirements, line filters for all vehicle power conversions systems shall be inductive above 40 Hz at a maximum. Line filters shall also have sufficient inductance to limit 60 Hz harmonic currents from substation rectifiers to levels below 6-car train limits.

C. Inductive Emissions Limits

1. Inductive Emissions shall not exceed the following rail to rail rms voltages:

Frequency	Limit
58 to 62 Hz	60 mV
97 to 103 Hz	90 mV
1200 to 7100 Hz	10 mV (For frequencies more than 150

	Hz from a Red or Orange Line train detection frequency, 20 mV shall be allowed)

Table 2-9 Inductive Emissions Limits

2. The total inductive emissions coupled into the cab signal antenna shall not exceed the equivalent of 50 ma of cab signal current circulating in the running rails at 990 Hz on the Orange Line.

3. The total inductive emissions coupled into the cab signal antenna shall not exceed the equivalent of 35 ma of cab signal current circulating in the running rails at 4550 Hz and 5525 Hz on the Red Line.

4. For measurement of inductive emissions, "Inductive Interference in Rapid Transit Signaling Systems, Volume II: Suggested Test Procedures", UMTA-MA-06-0153-85-8 shall be used. Modifications to the test procedure may be made to account for improvements in measuring equipment since the publication of the standard.

D. Radiated Emissions Limits

1. Broadband Radiated Emissions from the train to the wayside in the .15 MHz to 1 GHz range shall not exceed the limits described in EN 50121-3-2 for whole train emissions up to 1 GHz.

2. Radiated emissions shall be measured in accordance with EN 50121-3-2 with recalculation of limits based upon the actual placement of the measuring antenna.

3. Radiated emissions testing shall also examine ambient emissions and train broadband and narrow band emissions in the 1 GHz to 6 GHz range. Train emissions exceeding ambient emissions in this range by more than 10db shall be investigated and the source documented.

4. Non-broadcast narrow band emissions must be below a level which will interfere with any legal radio band.

   a. Additional narrow band radiated emission limits may be imposed by the necessity to avoid interference with systems of neighbors to the Authority's right of way.

2.07.03. Emissions Safety Analysis

A. The Contractor shall perform a FMECA and provide a Fault Tree Analysis on all traction inverters, auxiliary power converters, and low voltage power supplies. The probability of failures that could cause a car to exceed the conductive or inductive emissions limits shall be shown to be less than 1 event per 10^9 hours. [CDRL 02-20] Emissions detectors shall not be used to meet emissions safety requirements, unless approved by the Authority.

2.07.04. Human Exposure Field Limits

A. The vehicle shall not produce any health hazard to the public, passengers, train crew or maintenance personnel. The Contractor shall develop as part of the EMC Plan a process to control and mitigate any potential health hazards from electromagnetic fields or radiation. The limits expressed in the EMC Plan shall be based upon IEEE Std. C95.6 for frequencies below 3000 Hz and ANSI C95.1/IEEE C95.1 Standard -1999 for frequencies above 3000 Hz.

2.08: COMPATIBILITY

A. All specification requirements are applicable to both the Red and Orange Line cars, unless noted otherwise.

2.09: ITEMS REFERENCED

CDRL 02-01, “Red Line/Orange Line Common Parts”, (Ref: T 2.01.01.J)

CDRL 02-02, “Weight Management Program”, (Ref: T 2.01.07.A)

CDRL 02-03, “Carbody Thermal Conductivity (UA) Calculation”, (Ref: T 2.02.13.A)

CDRL 02-04, “Ride Quality Plan”, (Ref: T 2.02.16.E)

CDRL 02-05, “Ride Quality Test Report”, (Ref: T 2.02.16.F)

CDRL 02-06, “Reliability Prediction Report”, (Ref: T 2.03.05.A)

CDRL 02-07, “Reliability Program Plan”, (Ref: T 2.03.06.B)

CDRL 02-08, “Reliability Engineer”, (Ref: T 2.03.06.C)

CDRL 02-09, “Pilot Car Reliability Test”, (Ref: T 2.03.07.A)

CDRL 02-10, “Reliability Demonstration Plan”, (Ref: T 2.03.08.B)

CDRL 02-11, “6 Month Reliability Target”, (Ref: T 2.03.08.E.1)

CDRL 02-12, “12 Month Reliability Target”, (Ref: T 2.03.08.E.2)

CDRL 02-13, “Completion of the Reliability Demonstration Plan”, (Ref: T 2.03.08.F)

CDRL 02-14, “Preventive Maintenance Schedule”, (Ref: T 2.04.02.A)

CDRL 02-15, “Mean Time To Repair Estimate”, (Ref: T 2.04.02.D)

CDRL 02-16, “Maintainability Demonstration”, (Ref: T 2.04.04.A)

CDRL 02-17, “System Safety Program Plan”, (Ref: T 2.06.01.B.1)

CDRL 02-18, “Electromagnetic Compatibility Plan”, (Ref: T 2.07.01.A)

CDRL 02-19, “Verification of Emissions Limits”, (Ref: T 2.07.02.A)

CDRL 02-20, “Train to Wayside Emissions Safety Analysis”, (Ref: T 2.07.03.A)

CDRL 02-21 “Safety Certification” (Ref T 2.06.01.A)

CDRL 02-22 “Hazard List” (Ref T 2.06.01.B.2)

CDRL 02-23 “Preliminary Hazard Analysis” (Ref T2.06.01.B.3)

CDRL 02-24 “Hazard Tracking Log List” (Ref T2.06.01.B.4)

CDRL 02-25 “Loadweigh Compensation System” (Ref: T 2.02.01.B)

CDRL 02-26 “Safety Certification Plan” (Ref T 2.06.01.B)

2.10: REFERENCES

2.10.01. Standards Referenced

49 CFR Part 37 - Nondiscrimination On The Basis Of Disability In Programs Or Activities Receiving Federal Financial Assistance

49 CFR Part 38 - Enforcement Of Nondiscrimination On The Basis Of Handicap In Programs Or Activities Conducted By The Department Of Transportation

49 CFR Part 236 - Rules, Standards, And Instructions Governing The Installation, Inspection, Maintenance, And Repair Of Signal And Train Control Systems, Devices, And Appliances

49 CFR Part 238 - Passenger Equipment Safety Standards

ADA - Accessibility Guidelines for Transportation Vehicles

IEEE STD 16-2004 - Standard for Electrical and Electronic Control Apparatus on Rail Vehicles

ISO 2631 (1997) – Mechanical vibration and shock – Evaluation of Human Exposure to Whole – Body Vibration. Part 1: General Requirements

MIL-STD-882C – System Safety Program Requirements

NFPA 130 - National Fire Protection Agency - Fixed Guideway Transit and Passenger Rail Systems

UMTA-MA-06-0153-85-11, "Radiated Interference in Rapid Transit Systems, Volume II Suggested Test Procedures".

2.10.02. Technical Specification Cross References

T 10, Propulsion & Dynamic Braking
T 11, Trucks
T 12, Friction Brakes and Pneumatic Systems
T 16, Vehicle Monitoring System
T 22, Systems Assurance

PART T 03.00
CARBODY

Table of Contents

3.01: GENERAL

3.01.01. General Requirements

A. The carbody shall be designed for a service life in excess of 30 years, considering the most severe environmental and loading conditions as defined in the Technical Specification (T).

B. Not used.

C. Vehicles shall be configured as semi-permanently coupled Married Pairs consisting of a Cab car and a Non-Cab car with a hostler panel. The married cars shall be structurally the same, except for secondary structure that may support different equipment as required.

D. The carbody, including doors, windows and access panels, shall be watertight and shall not be subject to water leakage during carwash, or when operating at maximum speeds under extreme weather conditions, as specified in T 02, Vehicle Design Requirements.

E. Not used.

3.02: CARBODY MATERIALS

3.02.01. Structural Steel

A. All components used in the construction of the carbody shall be fabricated from stainless steel, American Iron and Steel Institute (AISI) type 301LN or approved equivalent. Stainless steel shall conform to the requirements of Materials & Workmanship section T 18.04, Stainless Steel.

B. Components such as bolsters, end draft sills, end sills/anticlimbers, structural shelves, corner posts and collision post stubs may be fabricated from High-Strength Low-Alloy (HSLA) steel per American Society for Testing and Materials (ASTM) A588, or approved equal. Selected steel shall have inherent corrosion resistance of at least four times that of plain carbon steel. HSLA shall conform to the requirements of Materials & Workmanship section T 18.05, High-Strength Low-Alloy Steel.

C. The Contractor shall submit material specifications for all materials to be used in the carbody, including chemical and physical properties in all conditions of hardness and post-welding. If any "approved equivalent" materials are used, a comparison to the above materials shall be provided. The specifications shall include the minimum mechanical properties considering the base materials and all post-weld conditions. Those mechanical properties shall include: tensile yield strength, compressive yield strength, shear yield strength, ultimate tensile strength, ultimate shear strength, elongation, modulus of elasticity, modulus of rigidity and Poisson's ratio. [CDRL 03-01]

3.02.02. General Welding

A. All critical weld joints of the underframe shall be full penetration welds that conform to American Welding Society (AWS) D1.1 prequalified welds.

B. All stainless steel to stainless steel welding visible from the exterior shall be laser welded. All visible welds shall have no discoloration, no displaced metal, and minimum indentation. Resistance spot welding may be proposed on a case by case basis, subject to Authority approval.

C. Hidden welds of stainless steel to stainless steel may be arc welded, if necessary, to achieve the structural requirements. Plug welds shall not be permitted.

D. All welding procedures shall conform to the applicable AWS requirements.

E. All welders shall be certified per AWS to perform the specific welds being applied. Certification shall be within the last six months or within the last year if the welder has been performing the same welds regularly over the past year. The Contractor shall submit weld certifications for all weld joints and welders that will be used during carbody manufacture. Refer to T 18.16 Welding, for additional technical requirements and CDRLs.

3.02.03. Welding Between HSLA and Stainless Steels

A. The weld joints of stainless steel to HSLA shall use arc welding and shall conform to AWS D1.1 (or AWS D1.3 for thin sheet) prequalified weld geometry.

B. Austenitic stainless steel filler metal shall be used for all welds.

C. All welds shall be primed using an acid etch type primer and painted with a polyurethane based paint system immediately after the Authority's inspector has reviewed the welding. The inspector shall be notified 24 hours prior to weld completion.

D. Complete procedures for structural welding of stainless steel to HSLA, from filler metal selection through post weld treatment, shall be submitted to the Authority for review and approval. [CDRL 03-02]

3.03: CARBODY DESIGN REQUIREMENTS

3.03.01. Carbody General Requirements

A. Not used

B. The Red and Orange Line carbody profiles shall be similar to the existing car profiles and conform to the dynamic clearance requirements of the Red and Orange Lines, respectively. The existing car profiles are provided in the appendix to the specification. The Contractor shall submit the new car profiles for Authority approval, subject to successful dynamic clearance testing. [CDRL 03-03]

C. The stainless steel exterior shall have a uniform brush finish with the grain direction parallel to the side sills. The grain direction on all door panels shall match the grain of the adjacent exterior finish. The Contractor shall submit six 12 inch x 12 inch (305 mm x 305 mm) samples of several standard finishes in the range of 120 to 320 grit for selection by the Authority. Samples shall include the anti-graffiti coating specified in T 03.03.05. [CDRL 03-04]

   1. Any mechanical operation to achieve the finish shall not use abrasive materials made of iron, iron oxide, steel, zinc, or any other undesirable materials that may cause contamination of the stainless steel surface.

D. The carbody shall incorporate Fiberglass Reinforced Plastic (FRP) masks on the No. 1 and No. 2 end walls which shall provide an aesthetically attractive and modern appearance. The masks shall be attached using fasteners at points with integral stainless steel reinforcement plates.

   1. The front mask of the Cab Car shall provide sufficient clearance between collision posts and mask face to allow the installation of the front destination sign.

   2. The masks shall be designed to direct water from the roof to the outer corners of the car, and minimize the flow of water over the ends. Refer to T 14, Interior & Exterior Appointments, for further detail and options.

E. Passenger side doors (as defined in T 06, Passenger Doors & Controls) shall be provided as follows:

   1. Three doorways per side on the Orange Line.

   2. Four doorways per side on the Red Line.

   3. All side doors shall provide a minimum 32 inch (813mm) wide clear opening with only one door leaf open. Door seals, handles, hand rails, etc. shall not infringe on the 32 inch (813mm) wide clear opening of any door leaf.

   4. Not used.

   5. The Contractor shall submit horizontal and vertical cross-sections of all door openings for Authority review and approval. [CDRL 03-05]

F. The carbody shall include provisions for mounting side passenger windows, cab side windows, Cab (or Hostler) and No. 2 end windows as required in T 14, Interior & Exterior Appointments. The Contractor shall submit plan, elevation and cross-sectional views of the windows, showing dimensions and details of the openings for Authority review and approval. [CDRL 03-06]

G. A hinged No. 1 end door shall be provided on the Cab Car, as defined in T 14, Interior & Exterior Appointments.

H. The No.1 end door of the Non-Cab car and No.2 End doors of both cars shall be sliding pocket type as defined in T 14, Interior & Exterior Appointments.

I. End gates (or between car Americans with Disabilities Act (ADA) barriers) and grab bars shall be provided at the ends of each car per T 14, Interior & Exterior Appointments.

3.03.02. Carshell Structure

A. The carshell structure shall incorporate anticlimbers on both car ends that are compatible with existing vehicles. The anticlimber shall incorporate provisions to accept a tow bar that is attached with a single vertical pin through the anticlimber. The upper surface of the anticlimber shall be diamond plate, or a similar permanent surface treatment that provides a non-slip walking surface. The Contractor shall submit detail drawings of the anticlimber for approval by the Authority. [CDRL 03-07]

B. The coupler and anchorage design shall allow a coupling speed up to 5 mph with no resulting damage to the coupler or anchorage.

C. A minimum of 10 jacking pads per car shall be provided. Pads shall be an integral part of the underframe structure and be designed with a diamond plate anti-slip surface or equivalent, as accepted by the Authority. Location of pads shall be identical to existing cars (see specification appendix for more information). Clearance for car hoist supports shall be maintained. Size of pads shall be no smaller than those on the existing cars. The Contractor shall submit location and detail drawings of the jacking pads for approval by the Authority. [CDRL 03-08]

D. Full height collision posts shall be incorporated on both sides of each end door. The collision posts shall provide a minimum 30 inch (762 mm) wide clear opening. Door seals, handles, hand rails, etc. shall not infringe on the clear opening width. Clear door height opening above finished floor shall be a minimum of 6 feet 3 inches (1.9 m).

   1. The collision post design shall have a continuous cross-section from below the lower plate of the end sill to a point at least 18 inches (457 mm) above the top plate of the end sill and shall be fully welded to the top and bottom plates of the end sill.

E. Corner posts shall be provided on left and right side of each end sill. The corner post design shall have a continuous cross-section from below the lower plate of the end sill to a point at least 18 inches (457 mm) above the top plate of the end sill and shall be fully welded to the top and bottom plates of the end sill.

F. Structural shelves shall be provided, located on both sides of the cab (and hostler panel end of the Non-Cab Car) under the end windows/windshields.

G. Full length, uninterrupted side sills shall be provided, such that there is no weld joint in the material. If drain lines pass through side sills, they shall be fabricated from stainless steel and be welded to the upper and lower horizontal faces of the sill. Drain lines shall extend at least 0.50 inch (12.7 mm) below the bottom of the sill.

H. The exterior of the carshell shall be smooth and free of corrugations. Interior stiffeners shall be provided as required to achieve the stiffness requirements of T 03.04.04.

1. Corrugated roofs may be proposed for Authority review and acceptance. Corrugated roofs, if proposed, shall be designed with a trough, or similar design feature, that prevents water from rushing into Heating, Ventilation and Air Conditioning (HVAC) pans during vehicle acceleration and deceleration.

I. The carbody shall utilize stainless steel floor beams and/or cross bearers as transverse members to support the floor panels. Corrugated stainless steel floor pans may also be proposed for use as a weight saving structure between floor beams/cross bearers and composite floor panels. Composite floor panel requirements are detailed in T 14, Interior & Exterior Appointments.

3.03.03. Carshell Secondary Structure and Design Details

A. Rain gutters shall be located at the transition of the roof to the sides, above all side passenger doors, cab side windows, end doors and windshields. The rain gutters shall be at least 1 inch (25 mm) wide and 1 inch (25 mm) deep.

B. Stainless steel sub-floor pans shall be included in the design and arranged to provide no less than 3 inches (76 mm) between the bottom of the floor panels and the top of the sub-floor pan. The sub-floor pan shall have integral stiffening to prevent buckling, sagging, or oil-canning in service. Sub-floor pan design and attachment technique shall be submitted to the Authority for review and approval. [CDRL 03-09]

C. A stainless steel pan shall be provided at the HVAC unit mounting locations. The pans shall be fabricated with continuously welded seams that are watertight without the use of sealants or adhesive. The pans shall collect all HVAC unit condensate and direct it through internal drain tubes. The longitudinal sides of the pans shall be fitted with splash shields, or incorporate a similar technique that contains rain water and prevents it from flowing over the side of the car, flooding the passenger entranceways. The splash shields, drain lines, and rain gutters shall prevent water from dripping at the doorways under worst case conditions cited in T 02, Vehicle Design Requirements.

D. Drains shall also be provided at all door thresholds, sliding door pockets and under windows, as required to drain areas prone to collecting standing water. All drains shall be designed to terminate under the car. Drains shall be fabricated from stainless steel tubing and be designed to be inherently protected from clogging (large radii bends, no fittings, etc) as a result of debris, leaves, dust, sand or dirt. If screens are utilized to prevent clogging, they shall be manufactured from stainless steel, be punched metal rather than wire mesh and be easily accessible for cleaning without the need for equipment removal. Drains shall be sized with consideration of the environmental conditions listed in T 02, Vehicle Design Requirements.

E. Door pockets shall be provided for all sliding doors. Secondary structure for pockets shall be mounted to the floor and side wall beams, as required.

1. Pockets shall be provided adjacent to each door leaf to house the exterior emergency door release described in T 06, Passenger Doors & Controls. The pocket shall be located approximately 12 inches (305 mm) above the finished floor and be covered by a diagonal cross cut, flexible elastomeric cover.

F. Not used.

3.03.04. Carbody Mounted Equipment

A. Equipment brackets shall be designed to support the underfloor equipment under all loading conditions as defined in the T 03.04, Performance. The bracket material shall be per T 3.02.01, Structural Steel. The configuration of all brackets shall ensure that all equipment greater than 25 lbs (11.3 kg) is safety hung and fastened with Authority accepted locking hardware. All undercar equipment brackets shall be attached to floor beams or underframe structure, but never on unsupported floor sheets. No through-floor fasteners shall be used.

B. The coupler carrier brackets and removable coupler stops (as required per T 04, Couplers & Draft Gear) shall be attached to floor beams or underframe structure.

C. All roof equipment brackets shall be bolted or welded to carlines or purlines, but never on unsupported roof sheets. The equipment shall not be bolted with fasteners in tension. No through-roof fasteners shall be used.

D. Stainless steel brackets shall be used to support cable cleats, piping clamps conduit runs, etc. The brackets shall be welded to the carbody or bolted to pre-existing mounting holes or tapping plates. Match drilling shall not be allowed. Stainless steel tapping plates shall be provided for all interior and exterior fixtures mounted to the carshell. The tapping plates shall provide a minimum of 0.375 inch (9.525 mm) distance from the edge of fastener to the edge of the plate.

E. Threaded inserts or tapping plates shall be provided for all components attached to the end mask. Inserts and plates shall be installed in blind holes, such that a water leak path is not created.

F. Stainless steel bosses shall be provided for all grounding points on the carshell. The bosses shall be pre-tapped through, prior to installation on the carbody.

G. Watertight provisions for mounting a radio and a Wi-Fi antenna on the roof shall be provided.

H. Equipment layout, bracket/cleat design and all attachment methods for all components installed under the car shall be submitted to the Authority for review and approval. [CDRL 03-10]

3.03.05. Carshell Coatings, Insulation and Surface Treatments

A. All stainless steel portions of the carshell shall be treated with a nitric or citric acid passivation bath. Passivation medium, concentration level and duration of treatment, as well as the rationale for selection, shall be proposed by the Contractor for review and approval by the Authority. [CDRL 03-11]

1. Stainless steel shall be cleaned in accordance with American Society for Testing and Materials (ASTM) A380. Post passivation testing shall be performed in accordance with ASTM A967. Test results, as well as visual approval of the aesthetics of the first carshell, shall be subject to Authority review and acceptance. The first approved carshell shall form the basis of pass-fail acceptance criteria of all future vehicles.

B. An anti-graffiti coating shall be applied to all exposed stainless steel surfaces, including the end and side door panels (with the exception of the roof), to ensure quick and easy removal of all potential types of graffiti. The anti-graffiti coating shall not yellow over time or promote snow or ice adhesion. Material shall be service proven on rail car applications. The coating shall have a minimum life of 10 years. Removal and re-application shall be easily accomplished. The Contractor shall submit material data sheets and service history of proposed coating, for Authority review and approval. [CDRL 03-12]

C. Sound deadening shall be applied to the inside surface of the sub-floor pan, side walls, end walls, the exterior surface of air ducts, and one side of the air duct splitter. The damping material shall be Daubert or Approved equal, spray-applied, non-asphalt polymer containing neither asbestos nor any other toxic materials.

D. Once the sound deadening coating has dried, thermal insulation shall be applied to the sub-floor pan, roof, side walls, end walls/masks and all closed sections of the carshell (such as hat sections welded to side skin). Insulation shall be secured using mechanical fasteners. Insulation material shall be glass fiber, or approved equal, with minimum thickness as required to meet all thermal and acoustical requirements, including all HVAC performance requirements. Insulation shall be flame resistant and conform to the flame, smoke and toxicity requirements of T 18, Materials & Workmanship. Urethane, asbestos, urea formaldehyde and polystyrene materials are prohibited.

E. HSLA Steel and/or stainless steel underframes shall be primed and painted with a polyurethane based paint system, in accordance with Materials & Workmanship section T 18.18.02, Paint & Painting. Stainless steel underframes shall be primed using an acid etch type primer prior to paint application.

3.04: PERFORMANCE

3.04.01. Strength Requirements

A. General

1. Not used.

2. In addition to the various requirements listed in this Specification, the new Orange and Red Line vehicles must also comply with all of the requirements specified in ASME RT-2-2008, "Safety Standard for Structural Requirements for

Heavy Rail Vehicles".

3. In all cases whenever "yielding", yield strength", "yield stress" or "permanent deformation" is specified or implied, it shall be understood that "as limited by stability considerations, such as column or plate buckling" is always implied. Similarly, whenever the allowable stress is defined as a percentage (for example, 50%) of the yield stress/strength, the same percentage applies to the critical buckling stress.

B. End Sill Compression

1. The carbody structure shall be designed to resist a load of 200,000 lbs (890,000 N) applied longitudinally to the anticlimbers in combination with vertical loads equal to the AW0 as well as the AW3 load conditions without exceeding 90% of yield strength of any member.

2. The carbody structure shall also be designed to resist a load of 250,000 lbs (1,112,000 N) applied longitudinally to the anticlimbers in combination with vertical loads equal to the AW0 as well as the AW3 load conditions, with localized crushing of the elements in the "Crush Zone" that is described in Section 3.04.03. The design of the end sill/anticlimber shall ensure that they remain attached to the carbody structure after the end crushable element arrangement is expended. Verification of adherence to this requirement may be proven through analysis.

3. In both cases, the anticlimber load area shall be 12 inches (305 mm) in width by 6 inches (152 mm) in height.

C. Coupler Anchor Compression and Tension

1. The carbody structure shall be designed to resist a longitudinal load of 110% of the maximum possible load (commonly called the disconnect or release load) produced by the coupler, as determined by the tolerance required for the design of the shear pins defined in Section 4.03.03, applied to the coupler mounting bracket in combination with vertical loads equal to the AW0 as well as the AW3 load conditions without exceeding 90% of the yield strength of any member. Loads shall be applied in both the longitudinally inward and outward directions.

D. Carbody Vertical Strength

1. The carbody structure shall be designed to resist a vertical load equal to an AW3 passenger load condition without exceeding 50% of the yield strength of any member.

E. Collision Post Strength

1. Each collision post and attachment shall resist a longitudinal shear load of 200,000 lbs (890,000 N) applied at the top of the end sill without exceeding 90% of the yield strength of any member.

2. Each collision post shall be designed to resist an inward longitudinal load of 75,000 lbs (334,000 N) acting at a point 18 inches (457 mm) above the top of the end sill. The direction of load shall be considered longitudinal and ± 15 degrees horizontally inward, such that three cases are considered. Both posts are to be loaded simultaneously without exceeding the yield strength of any member.

3. Each collision post shall also be designed to resist loads applied to an individual collision post18 inches (457 mm) above the top of the end sill, as described above in E2, beyond the elastic design load, until the center (mid-cross section) of the post has deflected at least one-third of its full depth measured at the middle of the post from a line connected between the top and bottom of the post when initially unloaded. The load shall remain above the elastic design load of 75,000 lbs. (334,000 N). There shall no complete separation of the post, its connection to the underframe, and its connection to either the roof structure or at the A-T plate.

F. Corner Post Strength

1. Each corner post and attachment shall resist two shear loads, applied separately to one post, equal to 75,000 lbs (334,000 N) applied at the top of the end sill without exceeding 90% of the yield strength of any member.. One load shall be applied in the longitudinal inward direction, and the second load in the transverse inward direction.

2. Each corner post shall be designed to resist inward loads of 25,000 lbs (111,000 N) acting at a point 18 inches (457 mm) above the top of the end sill without exceeding the yield strength of any member. The loads shall be separately applied in the transverse, longitudinal and 45 degrees horizontally inward directions, such that three cases are considered.

3. Each corner post shall also be designed to resist loads applied to an individual corner post18 inches (457 mm) above the top of the end sill, as described above in F2, beyond the elastic design load, until the center (mid-cross section) of the post has deflected at least one-third of its full depth measured at the middle of the post from a line connected between the top and bottom of the post when initially unloaded. The load shall remain above the elastic design load of 25,000 lbs. (111,000 N). There shall no complete separation of the post or in any of its connections to all other structural members.

G. Anticlimber Strength

1. The anticlimber shall resist a vertical load of 75,000 lbs (334,000 N) in either direction acting on any point on the anticlimber combined with an inward longitudinal load of 200,000 lbs (890,000 N) without exceeding the yield strength of any member. The vertical interface at the anticlimber shall consider one less rib than the total. Some localized deformation of the anticlimber is permitted.

H. Lateral Strength

1. The carbody shall be designed to resist an inward lateral load of 60,000 lbs (267,000 N) applied anywhere on the side sill without exceeding the yield

strength of any member. Some localized deformation of the side wall profile in the area of the load application is permitted. The load shall be distributed across an 8 foot (2.44 m) x 6 inch (152 mm) area of the side sill.

2. The carbody shall be designed to resist an inward lateral load of 10,000 lbs. (44,000 N) applied anywhere on the belt rail, and distributed across an 8 foot (2.44 m) x 6 inch (152 mm). No more than 3 inch (75 mm) of permanent structural deformation into the vehicle interior is allowed. No sharp edges or protrusions are permitted in the vehicle interior.

I. Structural Shelf

1. The carbody structural shelf shall be designed to resist an inward longitudinal load of 15,000 lbs (66,700 N) applied anywhere along the length of the structural shelf without exceeding 90% of the yield strength of any member.

J. Jacking Pad Strength

1. The carbody, jacking pads and support structure shall be capable of supporting a fully assembled car, with both trucks hanging from the carbody, on any two diagonally-opposite jacking pads, without exceeding 90% of the yield strength of any member.

K. Truck-to-Carbody Connection

1. The truck-to-carbody connection shall provide a truck lifting provision, and a safety connection in the event of an accident.

2. The truck-to-carbody connection shall support the complete weight of the truck when the carbody is raised with the trucks unsupported. Under this condition, all structural members of the carbody and the truck-to-carbody connection shall not exceed 50% of yield strength.

3. The truck-to-carbody connection shall withstand a horizontal load of 150,000 lbs (667,000 N) applied anywhere on the truck frame in a direction through the center of truck rotation without exceeding the ultimate strength in the attachment mechanism. The required resistance to the 150,000 lbs (667,000 N) horizontal load shall be available at any possible position of the truck in its vertical suspension travel, including the condition of the vehicle raised off the track with the truck hanging from the vehicle, and shall not depend on external vertical loading nor upon bolster anchor rods.. The strength of the truck and the supporting carbody structure shall be sufficient to develop the ultimate horizontal strength of the attachment mechanism as specified.

4. Adherence to these requirements may be proven through analysis.

L. Roof Strength

1. All parts of the roof, as well as roof equipment covers, shall be capable of supporting, without permanent deformation, 300 lbf (1300 N) load distributed over an area of 6 square inch (39 sq-cm), applied anywhere on the roof.

2. The roof sub-structure and skin shall be designed to support a uniform pressure of 50 lb/sq-ft (244 kg/sq-m) over the entire roof surface.

M. Rollover

1. The vehicle shall be designed to rest on its roof so that any structural damage in occupied areas is limited to the roof sheathing and roof framing members. Deformation to the roof sheathing and framing is allowed to the extent necessary to permit the vehicle to be uniformly supported directly on the top chords of the side frames and end frames. For this condition, the allowable stress for the structure in the occupied zones of the carbody shall be one-half yield or one-half of the critical buckling stress, whichever is less.

N. Equipment Bracket Design Strength

1. All equipment brackets for all underfloor and roof-mounted equipment and any associated carbody structure shall be designed for loads of ±5g longitudinal, ±3g vertical and ±3g lateral (applied separately but in combination with the 1g vertical downward load of the weight of the equipment) without exceeding the ultimate strength of the material. These loadings result in a total of six load cases.

3.04.02. Fatigue Requirements

A. Fatigue strength requirements shall be in accordance with the following table. The fatigue loads shall result in stresses that are below the fatigue stress limits determined in T 03.04.05. Fulfillment of all requirements shown below shall be confirmed through Finite Element Analysis (FEA) analysis:

Description	**Requirement**
Coupler Compression and Tension	At both AW0 and AW3 loading with ±0.2g longitudinal dynamic load applied at the coupler anchors.
Carbody Vertical Bending	At AW3 loading, with ±0.3g vertical dynamic load.
Carbody Lateral Bending	At AW3 loading, with ±0.2g lateral dynamic load.
Combined Vertical and Lateral Bending	Combined vertical and lateral fatigue loads resulting in maximum fatigue damage.
Carbody Equipment Bracket Loads	At AW3 loading, with ±0.2g of the equipment weight in the vertical, lateral and longitudinal directions in any combination providing the maximum fatigue damage (applied to all brackets).

3.04.03. Crashworthiness

A. The Red and Orange Line cars shall be designed to provide increased safety in the event of a collision by utilizing energy absorption techniques in the design of the carbody structure and coupler:

   1. Vehicles that experience ‘hard coupling’ at closing speeds 5 miles per hour (8 km/hr) and lower shall suffer no damage. Refer to T 04, Coupler & Draft Gear, for detailed requirements.

B. A 'Crush Zone' shall provide a sufficient length of controlled, longitudinal vehicle deformation, such that each cars' front end structure absorbs approximately 600 kft-lb (814 kJ) of energy before deformation begins in any other area of the vehicle. Energy absorption by the coupler retraction may be included in the total. Additional requirements of the crush zone:

   1. The crushable elements shall not deform when subjected to a force of 150,000 lbs (667 kN), but fully compress before any other area of the vehicle deforms. The crushable element(s) shall be easily removable and replaceable. Welding or torches shall not be required to remove a crushed element or install a replacement.

   2. The design of the front end shall not impact current Authority operations, which include access and egress through the end door and emergency evacuation from end doors.

   3. The crushable element(s) shall be fitted with anticlimber ribs, or similar devices that ensure vehicles engage and do not lift from the tracks during a crash.

   4. Conventional anticlimber ribs, which are an integral part of the end sill, shall engage if the element is fully crushed by an impact delivered from an oncoming train from any angle and orientation feasible anywhere in the Authority's Right of Way.

C. The Contractor shall propose a design to satisfy the crashworthiness requirements of this specification, as well as the various crashworthiness requirements specified in ASME RT-2-2008, whichever are more stringent. Layout of elements, calculated energy absorption per car and crushable length shall be submitted for Authority review and approval. [CDRL 03-13] Included in the submittal shall be the design requirements of the coupler that allow deformation to occur without shearing the coupler anchor mounting bolts. Any lost passenger and/or crew volume due to the incorporation of a crush zone shall also be addressed in the deliverable.

D. The end underframe shall be designed to ensure that in higher speed collisions, the crush zone shall be displaced, allowing anticlimbers to engage and transmit kinetic energy into the structural elements of the car body. The front end of the vehicles (from bolster to anticlimber) shall be designed to deform after the crush zone is depleted and crush in a controlled manner to absorb more energy from the collision and further reduce the forces imparted to passengers and crew. The failure of the end underframe shall start with crushing or buckling of the end structure members rather than shearing or failure of weld joints.

E. The crash performance shall be demonstrated by an analysis of two trains colliding that predicts the non-linear deformation under various circumstances. The analysis shall consider: two 6-car trains in all combinations of AW0 through AW3 conditions, with one stationary with service brakes applied and the other having an initial speed of 5 mph (8 km/hr), 15 mph (24.1 km/hr) and 25 mph (36.7 km/hr).

1. The crash analysis shall include a video animation of the crashes with graphs of force and deflection versus time. The animation shall accurately depict the progressive collapse, energy absorbed and the post-crash condition of vehicles. [CDRL 03-14]

F. The crushable element(s) shall be tested to ensure that the device(s) absorb energy in accordance with the analysis. Test results that vary significantly from the analysis shall be cause for a redesign of the crush zone. Test procedures and results shall be approved by the Authority prior to acceptance of the carshell final design. [CDRL 03-15]

3.04.04. Stiffness, Flatness and Camber Requirements

A. The completed vehicle shall have a positive camber at AW0 condition that is no greater than .75 inches (19.0 mm), measured at the midpoint between the truck centers on both side sills. The datum will be considered to be the straight line between the two truck centers. At AW3 condition, the camber shall be greater than zero.

B. The carbody deflection under any conditions shall not have an effect on the operation or sealing of side doors, end doors or cab windows, in either dynamic or static conditions.

C. The carbody natural frequency shall be greater than the square root of 2 times the primary suspension natural frequency such that there will be no influence on vehicle vibration for all operating conditions. The natural frequency shall be demonstrated by FEA analysis.

D. The exterior body sides and ends shall not have any visible creases and any deviation from 100% flat shall not exceed the lesser of .09 inch (2.3 mm) or 1/300 of the span between adjacent members.

E. Side walls and end walls shall incorporate a sufficient quantity of internal stiffeners such that a 25 lbf (111 N) load applied over a .5 square inch (3.2 sq-cm) surface area shall not result in a deflection of more than .030 inches (0.76 mm).

F. The floor beams shall not deflect more than 1/250 of their span with a uniformly distributed load equivalent to AW3 is applied.

3.04.05. Allowable Fatigue Stresses

A. The allowable fatigue stress shall be determined by multiplying the static stress at AW3 by the dynamic factor. The resulting stress shall be below the design fatigue limit listed in AWS D1.1, for non-redundant or redundant structures, as applicable.

B. The Contractor shall submit a document identifying all the weld joints used in the carbody and the allowable fatigue stresses for each weld joint. Stresses applied both transverse and parallel to the weld axis shall be identified. The weld limits shall conform to AWS D1.1 for non-redundant structures at 10,000,000 cycles. [CDRL 03-16]

3.04.06. Stress Analysis

A. The carbody stress analyses shall consist of a linear elastic Finite Element Analysis (FEA) and non-linear FEA using industry recognized computer programs such as NASTRAN, ANSYS, etc.

B. For the FEA analyses, all carbody load conditions shall include the distributed structural weight, the distributed interior package weight and the mounted equipment weights. The weight of these features shall be applied as gravitational forces, distributed forces and point masses as required to best simulate the actual load conditions of the finished car and passenger loading. The Contractor shall submit the FEA model and load distribution for each load case for approval by the Authority prior to performing the analyses. [CDRL 03-17]

C. The Contractor shall perform FEA analyses, and detailed analytical calculations as required to demonstrate that the carbody stresses and carbody bracket stresses are acceptable, considering all loading conditions of Section T 03.03, Carbody Design Requirements. [CDRL 03-18]

D. For the FEA, the material properties used shall be the minimum yield and ultimate strengths as defined by the relevant material standards. For materials whose yield points are not clearly defined, the 0.2-percent offset method shall be used to determine the yield strength.

E. For all weld joints that are not accurately represented in the FEA, detailed analytical calculations shall be provided.

3.04.07. Water-Tightness

A. The carbody shall be watertight under all operating conditions and the most extreme weather conditions, including operation through the Authority car wash.

B. A water-tightness test shall be conducted on all completely welded carbodies prior to installing sound deadening, insulation, subfloor and interior panels, using production windows, all production exterior light fixtures and production antennas. Contractor may elect to install doors prior to the test. No water shall enter the vehicle.

C. A second water-tightness test shall be conducted on all completed cars per T 20, 22.03, Water Tightness Testing.

D. Alternate testing arrangements that satisfy the intent of this section may be proposed for Authority consideration.

3.04.08. Clearances

A. The minimum allowable clearance above the running rail for the carbody and carbody parts in the worst conditions of track geometry, fully worn wheels, broken or deflated springs, maximum passenger load, etc., shall not be less than 4.75 inches (121 mm).

B. For carbody mounted equipment less than 5 (127 mm) inches above top of third rail, the lateral clearance between carbody mounted equipment and the third rail shall not be less than 35 inches (890 mm).

C. For carbody mounted equipment greater than 35 inches from third rail, the vertical clearance between carbody mounted equipment and top of rail shall not be less than 4.75 inches (121 mm).

D. Wayside clearances shall be determined by comparison of the dynamic envelope under worst conditions of track geometry, fully worn wheels, dynamic motion, and the wayside clearance envelope. The Contractor shall submit the clearance analysis and clearance drawings showing the carbody envelope relative to the wayside clearance envelope for all track conditions and all positions along the length of the car. [CDRL 03-19]

3.04.09. Cleaning

A. The carbody and all exposed features shall be capable of being washed by any of the Authority car wash facilities and cleaning solutions without damaging or degrading the finishes and materials.

3.04.10. Carshell Weight

A. The Contractor shall provide regular weight estimates throughout the carbody design process, with at least one submittal each month. The weight data shall include an estimate of the location of the center of gravity. Carshell weight records shall be submitted in the Car History Book with each completed vehicle. See T 02, Vehicle Design Requirements, for detailed weight reporting requirements.

3.05: QUALIFICATION TESTING

3.05.01. General

A. The following tests shall be conducted on the first carshell. The Contractor shall submit test procedures and proposed test facility to the Authority for review and approval prior to commencement of testing. [CDRL 03-20]

B. The Contractor may perform all testing during the compression test, if desired.

C. Upon completion of the tests, test Reports shall be submitted for Authority review and approval. [CDRL 03-21]

D. Carshell First Article Inspection (FAI) acceptance shall be subject to successful completion of the Qualification Tests as well as Production Conformance Tests of T 03.06.

3.05.02. Weld Tests

A. Representative samples of all carbody structural welds, both fusion and resistance, shall be produced using the processes and equipment to be used in production. The weld samples shall be tested to confirm they meet the design strength requirements.

3.05.03. Carbody Compression Test

A. The carbody compression test shall confirm compliance with the requirements of T 03.04.01.B.1.

B. Prior to performing each of the specified carbody load tests, the carbody shall be subject to three repetitions at the loadings specified in each test to avoid false indications due to residual stresses. This requirement may be omitted during the vertical load test.

C. The test carbody shall be structurally complete, but shall not include windows, doors, secondary structure, seats, interior linings, floor panels, insulation, sound deadening, and equipment. Equipment brackets and supports shall be complete, including truck anchor brackets and center pins as applicable.

D. The carbody shall be loaded at the beginning of testing with distributed loads that simulate AW0 load of windows, doors, secondary structure, seats, interior linings, floor panels, and equipment in the best way possible. Cantilever seat loads shall be simulated correctly. During the jacking tests, simulated truck loads shall be applied to the actual truck hanger brackets.

E. The load applications shall be through hydraulic actuators with independent force sensors at each point of load. The actuators and sensors shall have current certified calibration to within 1% accuracy. The longitudinal compression load shall be applied at the anticlimber centerline over an area of 12 inches (305 mm) wide by 6 inches (152 mm) high. During compression loading, the vertical load shall simulate the AW0 condition plus AW3 passenger load applied as a distributed load over the seats and floor. The compression load shall be applied in increments of 50,000 lbs (222,000 N), 100,000 lbs (445,000 N), 150,000 lbs (667,000 N), 175,000 lbs (778,000 N) and 200,000 lbs (890,000 N), being reduced to 10,000 lbs (44,500 N) after each increment.

F. A minimum of 200 strain gauges shall be applied at approved locations on the carbody. Locations shall be determined by the FEA, Contractor experience and as requested by the Authority. All strain gauges shall be calibrated for zero reading with AW0 load applied. Strain gauge readings shall be recorded at the peak of each load application and at all load reductions.

G. The vertical deflection of the carbody shall be measured along both side sills using a minimum of seven electronic deflection devices per side. The resulting deflection shall be considered as the average of both sides.

H. The longitudinal deflection of the carbody shall be measured using two deflection gauges located at the end sill on either side of where the compression load is applied.

Deflection gauges shall also be installed to measure the two diagonal dimensions of all door and window openings.

I. During the test, no strain gauge reading shall indicate stress in excess of 90% of yield, nor shall there be any permanent deflection indicated. Vertical, longitudinal and diagonal deflections (and at least 80% of the strain gauges reading more than 25% of the allowable stress for the particular load case) shall be within ±15% of the FEA results, with none less accurate than ±30%. The Contractor shall reconcile all differences between the FEA and the test results to the satisfaction of the Authority. Any deviations that occur in highly stressed areas that cannot be satisfactorily explained will result in a retest of the structure and implementation of modifications and additional FEA as required.

3.05.04. Coupler Anchor Compression and Tension Test

A. The compression and tension tests at the coupler shall confirm compliance with the requirements of T 03.04.01.C. The test procedures, instrumentation, data recording and acceptance criteria shall be as required for the Carbody Compression Test, with the applicable loads applied to the coupler anchor and similar vertical loading as called for during the compression test.

3.05.05. Carbody Vertical Load Test

A. The carbody vertical load test shall confirm compliance with the requirements of T 03.04.01.D, Carbody Vertical Strength. Test procedures, instrumentation, data recording shall be as required for the Carbody Compression Test with the addition of lateral deflection gauges at the belt rail height at all door posts and corner posts (as a minimum). The resulting deflection shall be considered as the average of both sides.

B. The vertical load shall be applied in steps (AW1, AW2, AW3).

C. During the test, no strain gauge reading shall indicate stress in excess of 50% of yield, nor shall there be any permanent deflection indicated or residual stress greater than 5% at the final AW0 load. Vertical, lateral and diagonal deflections and at least 80% of all strain gauges shall be within ±15% of the FEA results, with none less accurate than ±30%. The vertical deflection and change in camber shall comply with the requirements of T 3.04.04.A, Stiffness, Flatness and Camber Requirements. The Contractor shall reconcile all differences between the FEA and the test results to the satisfaction of the Authority. Any deviations that occur in highly stressed areas that cannot be satisfactorily explained will result in a retest of the structure and implementation of modifications and additional FEA as required.

3.05.06. Carbody Diagonal Jacking Test

A. The carbody diagonal jacking test shall confirm compliance with the requirements of T 03.04.01.J, Jacking Pad Strength. Test procedures, instrumentation and data recording shall be as required for the Carbody Compression Test.

B. During the test, no strain gauge reading shall indicate stress in excess of 90% of yield, nor shall there be any permanent deflection indicated. Window and door deflections and at least 80% of all strain gauges shall be within ±15% of the FEA results, with none less accurate than ±30%. The Contractor shall reconcile all differences between the FEA and the test results to the satisfaction of the Authority. Any deviations that occur in highly stressed areas that cannot be satisfactorily explained will result in a retest of the structure, implementation of modifications and additional FEA as required.

3.05.07. Carbody Natural Frequency Test

A. The carbody natural frequency test shall confirm the value of the carbody natural frequency determined by analysis per T 03.04.04.C, Carbody Natural Frequency.

3.05.08. Roof Strength Test

A. The roof shall be subjected to the following loads with suffering from permanent deformation:

1. A 300 lbf (1300 N) load shall be distributed over a 6 square inch (39 sq-cm) surface area, applied anywhere on the roof.

2. A uniform pressure of 50 lb/sq-ft (244 kg/sq-m) over the entire roof surface.

3.05.09. Equipment Supporting Structure Strength Tests

A. Equipment weights shall be simulated to ensure all underframe and roof structure and carbody brackets resist ±5g longitudinal, ±3g vertical and ±3g lateral (applied separately) without damage. (These tests may be satisfied with a submittal of FEA modeling).

3.05.10. Stiffness Tests

A. A 25 lbf (111 N) load applied over a .5 square inch (3.2 sq-cm) surface area of the sidewall shall not result in a deflection of more than .030 inches (0.76 mm).

B. The floor beams shall not deflect more than 1/250 of their span under a load equivalent to the beam's portion of a uniformly distributed AW3 car loading.

3.05.11. Collision Post Elastic Tests

A. Two collision post elastic tests shall be separately performed to confirm compliance with the requirements of T 03.04.01.E.1 and T 03.04.01.E.2. The test procedures, instrumentation, data recording and acceptance criteria shall be as required for the Carbody Compression Test, with the applicable loads applied to the collision posts and similar vertical loading as called for during the compression test.

B. At least ten (10) strain gauges shall be applied to each of the tested collision posts and its supporting structure at locations approved by the Engineer.

C. At least five (5) deflection gauges shall be applied along the length of each tested collision post at locations approved by the Engineer.

D. Loads which are specified in a range on either side of the longitudinal direction need only to be applied in the longitudinal direction (0 degrees).

3.05.12. Collision Post Elastic-Plastic Test

A. The collision post elastic test shall confirm compliance with the requirements of T 03.04.01.E.3 and demonstrate the ductility of the collision posts. Except as defined below, the test procedures, instrumentation, data recording and acceptance criteria shall be as required for the Carbody Compression Test, with the applicable load applied to the collision post.

B. In lieu of the test specimen being a structurally complete carbody, an alternate test specimen may be proposed by the Contractor.

1. This alternate test specimen must duplicate production components and their connections/attachments.

2. The alternate test specimen must comply with the special test article requirements described in Section 10.3.5.1 of ASME RT-2-2008.

3. Drawings for the proposed alternate test specimen shall be submitted to the Engineer for approval significantly in advance of the test to allow for possible re-design per the Engineer's comments and the subsequent manufacturing. At a minimum, these drawings shall be submitted twelve (12) weeks in advance of the test. [CDRL 03-22]

C. Application of a vertical load is not required for this test.

D. The direction of the applied horizontal load shall be in accordance with the worst-case loading condition as determined by the results of the required structural analysis, unless approved otherwise by the Engineer.

E. At least ten (10) strain gauges shall be applied to the tested collision post and its supporting structure at locations approved by the Engineer.

F. At least five (5) deflection gauges shall be applied along the length of the tested collision post at locations approved by the Engineer.

G. The test results shall verify the following:

1. The applied load remains above the elastic design load of 75,000 lbs (334,000 N).

2. The mid-cross section of the post has deflected a minimum of one-third of its full depth at the mid-length location along the post when initially unloaded.

3. The post and its connections to all other structural members have not completely separately.

3.05.13. Corner Post Elastic Tests

A. Two corner post elastic tests shall be separately performed to confirm compliance with the requirements of T 03.04.01.F.1 and T 03.04.01.F.2. The test procedures, instrumentation, data recording and acceptance criteria shall be as required for the Carbody Compression Test, with the applicable loads applied to the corner post and similar vertical loading as called for during the compression test.

B. At least ten (10) strain gauges shall be applied to the tested corner post and its supporting structure at locations approved by the Engineer.

C. At least five (5) deflection gauges shall be applied along the length the tested corner post at locations approved by the Engineer.

D. The direction of the applied horizontal load shall be in accordance with the worst-case loading condition as determined by the results of the required structural analysis, unless approved otherwise by the Engineer.

3.05.14. Corner Post Elastic-Plastic Test

A. The corner post elastic test shall confirm compliance with the requirements of T 03.04.01.F.3 and demonstrate the ductility of the corner posts. Except as defined below, the test procedures, instrumentation, data recording and acceptance criteria shall be as required for the Carbody Compression Test, with the applicable load applied to the collision post.

B. In lieu of the test specimen being a structurally complete carbody, an alternate test specimen may be proposed by the Contractor.

1. This alternate test specimen must duplicate production components and their connections/attachments.

2. The alternate test specimen must comply with the special test article requirements described in Section 10.3.5.1 of ASME RT-2-2008.

3. Drawings for the proposed alternate test specimen shall be submitted to the Engineer for approval significantly in advance of the test to allow for possible re-design per the Engineer's comments and the subsequent manufacturing. At a minimum, these drawings shall be submitted twelve (12) weeks in advance of the test. [CDRL 03-22]

C. Application of a vertical load is not required for this test.

D. The direction of the applied horizontal load shall be in accordance with the worst-case loading condition as determined by the results of the required structural analysis, unless approved otherwise by the Engineer.

E. At least ten (10) strain gauges shall be applied to the tested corner post and its supporting structure at locations approved by the Engineer.

F. At least five (5) deflection gauges shall be applied along the length of the tested corner post at locations approved by the Engineer.

G. The test results shall verify the following:

1. The applied load remains above the elastic design load of 25,000 lbs (111,000 N).
2. The mid-cross section of the post has deflected a minimum of one-third of its full depth at the mid-length location along the post when initially unloaded.
3. The post and its connections to all other structural members have not completely separately.

3.05.15. Coupling Impact Tests

A. As per the requirements in Section 10.5 of ASME RT-2-2008, these tests shall serve to demonstrate that the vehicle can remain fully serviceable under coupling impacts up to the coupling speed requirements of T 03.04.03.A.1.

B. This test requires that the production version of the complete mechanical coupler assembly, including the draft gear, shear pins, radial carrier and carbody mounted coupler anchor bracket, shall be applied to the carbody structure test specimen with the actual production fasteners in order to duplicate the actual design.

   1. The Contractor shall provide the appropriate analysis to define the number of cars in each train, assuming that each train has the same number of married-pair cars and each car has the same passenger load, for each passenger load condition (AW0, AW1, AW2 and AW3) in order to achieve the maximum load-deflection in the draft gear without exceeding its energy absorption limit, when the closing speed between the trains is at 5 mph (8.0 km/hr). In addition, the analysis shall also define the maximum closing speed that can occur between two (2) AW3 loaded 6-car trains without exceeding the energy absorption limit of the draft gears. This analysis shall be submitted to the Engineer for approval significantly in advance of the test to allow for the determination of the train configurations and closing speeds that will be required for these coupling impact tests. At a minimum, this analysis shall be submitted twelve (12) weeks in advance of the test. [CDRL 03-23]

   2. At a minimum, it is expected that at least two coupling impact tests shall be performed. It is expected that one test shall be based on two (2) AW3 loaded 6-car trains at the appropriate closing speed, which will be determined in the analysis described in B1 above. Depending on the results of the analysis, the other shall be based on a worst-case condition, as chosen by the Engineer, at a closing speed of 5 mph (8.0 km/hr).

   3. Prior to submitting the test procedure for these tests, the Contractor shall submit his proposal for conducting these tests. That proposal shall generally describe the test specimens, including the method of representing two appropriately loaded trains, and also define the characteristics/parameters that will be measured and recorded during these tests. At a minimum, it is expected that the closing speed and the load-deflection of the appropriate draft gears will be measured. This proposal shall be submitted to the Engineer for approval significantly in advance of the test. At a minimum, this proposal shall be submitted twelve (12) weeks in advance of the test. [CDRL 03-24]

4. The Contractor shall submit the detailed test procedure for the coupling impact tests, which shall be based on the above-described proposal. The test procedure shall contain all of the required details for performing the tests. This test procedure shall be submitted to the Engineer for approval significantly in advance of the tests. At a minimum, this test procedure shall be submitted ten (10) weeks in advance of the tests.

3.05.16. ASTM E-119 Floor Fire Test

A. A 10 foot (3.05 m) section of assembled flooring shall pass a 30 minute floor fire test performed in accordance with ASTM E-119. The floor section shall include representative penetrations for cable entrances, piping entrances and representative floor panel joints. All insulation in the floor shall be included in the tests. See section T 14, Interior & Exterior Appointments, for floor panel and lining details.

B. For information only, the test shall continue after completion of the 30 minutes to determine the time to failure and failure mode.

3.06: PRODUCTION CONFORMANCE TESTS

3.06.01. Carbody Water-tightness Tests

A. Each completed carshell shall be subjected to water testing per T 03.04.07, Water Tightness. The test report shall be included in the Car History Book.

3.06.02. Carbody Weight

A. Each carshell shall be weighed prior to shipment to final assembly. The certified weight ticket shall be produced automatically by the weight scales, and shall be included in the Car History Book.

3.07: RELIABILITY

A. The carbody shall be designed for a service life in excess of 30 years, considering the most severe environmental and loading conditions as defined in T 02, Vehicle Design Requirements.

B. The carbody shall maintain all dimensional stiffness and camber requirements for the entire service life.

3.08: MAINTAINABILITY

A. Paint shall be durable and shall not peel, loosen or fade for a minimum of 15 years in service, including regular washing using the Authority car wash and cleaning solutions.

B. The carbody anti-graffiti coating shall remain intact, without any change in appearance, and maintain the same performance for at least 10 years of service, including regular washing and graffiti removal.

3.09: SAFETY

A. All exposed metal shall be as smooth as possible, with no sharp edges, sharp corners or burrs.

B. There shall be no visible fasteners or fastener heads, except for flush-head fasteners used to attach the end mask and thresholds.

3.10: COMPATIBILITY

A. The carbody designs shall incorporate identical or interchangeable components, such as windows, signs, seats, etc. that interface with the carbody.

B. The Red and Orange Line carbodies shall incorporate similar or identical structural components and subassemblies where possible, while maintaining the dimensional characteristics unique to each design.

C. The truck-to-carbody interfaces shall be identical for both the Red and Orange Line carbodies, including all suspension and structural attachments, wiring and air system connections.

3.11: CDRL ITEMS REFERENCED

CDRL 03-01, “Material Specifications”, (Ref: T 3.02.01.C)

CDRL 03-02, “Weld Procedure – HSLA to Stainless Steel”, (Ref: T 3.02.03.D)

CDRL 03-03, “Car Profile Drawings”, (Ref: T 3.03.01.B)

CDRL 03-04, “Brush Finish Samples”, (Ref: T 3.03.01.C)

CDRL 03-05, “Doors Cross-sections and Dimensions”, (Ref: T 3.03.01.E.5)

CDRL 03-06, “Windows Cross-sections and Dimensions”, (Ref: T 3.03.01.F)

CDRL 03-07, “Anticlimber Details”, (Ref: T 3.03.02.A)

CDRL 03-08, “Jacking Pads”, (Ref: T 3.03.02.C)

CDRL 03-09, “Subfloor Pans”, (Ref: T 3.03.03.B)

CDRL 03-10, “Underfloor Equipment Layout”, (Ref: T 3.03.04.H)

CDRL 03-11, “Carshell Passivation”, (Ref: T 3.03.05.A)

CDRL 03-12, “Anti-Graffiti Coating Data”, (Ref: T 3.03.05.B)

CDRL 03-13, “Crush Zone Design", (Ref: T 3.04.03.C)

CDRL 03-14, "Crashworthiness Analysis”, (Ref: T 3.04.03.E.1)

CDRL 03-15, “Crushable Element Testing”, (Ref: T 3.04.03.F)

CDRL 03-16, “Fatigue Allowable Stresses”, (Ref: T 3.04.05.B)

CDRL 03-17, “FEA Models and Load Cases”, (Ref: T 3.04.06.B)

CDRL 03-18, “FEA Results”, (Ref: T 3.04.06.C)

CDRL 03-19, “Carbody Clearances”, (Ref: T 3.04.08.D)

CDRL 03-20, “Qualification Test Procedures”, (Ref: T 3.05.01.A)

CDRL 03-21, “Qualification Test Results”, (Ref: T 3.05.01.C)

CDRL 03-22, "Alternate Test Specimen Drawings", (Ref: T 3.05.12.B.3 and T 3.05.14.B.3)

CDRL 03-23, "Analysis for Coupling Impact Tests", (Ref: T 3.05.15.B.1)

CDRL 03-24, "Proposal for Conducting the Coupling Impact Tests", (Ref: T 3.05.15.B.3)

3.12: REFERENCES

3.12.01. Standards Referenced

AAR M-201, Steel Castings

AISI 301LN, Stainless Steel Alloy

ASME RT-2-2008, Safety Standard for Structural Requirements for Heavy Rail Transit Vehicles

ASTM A380, Standard Practice for Cleaning, Descaling, and Passivation of Stainless Steel Parts, Equipment, and Systems

ASTM A588, Standard Specification for High-Strength Low-Alloy Structural Steel with 50 ksi Minimum Yield Point to 4 in. Thick

ASTM A666, Standard Specification for Austenitic Stainless Steel Sheet, Strip, Plate, and Flat Bar

ASTM A967, Standard Specification for Chemical Passivation Treatments for Stainless Steel Parts

ASTM E94, Standard Guide for Radiographic Testing

ASTM E119, Method for Fire Tests of Building Construction and Materials

ASTM E125, Standard Reference Photographs for Magnetic Particle Indications on Ferrous Castings

ASTM E162, Standard Test Method for Surface Flammability of Materials Using a Radiant Heat Energy Source

ASTM E165, Standard Test Method for Liquid Penetrant Examination

ASTM E390, Standard Reference Radiographs for Steel Fusion Welds

ASTM E446, Standard Reference Radiographs for Steel Castings Up to 2 in. in Thickness

ASTM E662, Test Method for Specific Optical Density of Smoke Generated by Solid Materials

ASTM E709, Standard Guide for Magnetic Particle Examination

AWS D1.1, Structural Welding Code - Steel

AWS D1.3, Structural Welding Code - Sheet Steel

NFPA 130, Standard for Fixed Guideway Transit Systems

3.12.02. Technical Specification Cross References

T 01, General,
T 02, Vehicle Design Requirements
T 04, Coupler & Draft Gear
T 06, Passenger Doors and Controls
T 11, Trucks
T 14, Interior & Exterior Appointments
T 18, Materials & Workmanship
T 20, Testing & Validation

PART T 04.00
COUPLER & DRAFT GEAR

Table of Contents

4.01: GENERAL

A. The #4 Red Line cars and #14 Orange Line cars shall be arranged as semi-permanently coupled Married Pairs with a cab section at the No. 1 end of the Cab Car and a hostler panel at the No. 1 end of the Non-Cab Car.

B. The No. 1 end of each car shall be equipped with a hinged head, flat face, hook-type mechanical coupler with draft gear and integrated automatic electric and pneumatic connections. The coupler shall be capable of fully automatic and manual operation and be similar in design to the Dellner coupler as used on the #3 Red Line cars. The couplers shall include moving electric heads that advance after mechanical coupling, as opposed to the fixed heads that engage simultaneously with mechanical coupling.

C. Couplers currently in use on the #3 Red Line Cars are Dellner - Tomlinson style. The #12 Orange Line cars are fitted with Walton Dresser - Waugh RT-119. #4 Red Line couplers shall be mechanically compatible with the #2 and #3 Red Line cars. #14 Orange Line couplers shall be mechanically compatible with the #12 Orange Line cars.

1. Not used.

D. A mechanically pinned semi-permanent coupler/drawbar arrangement shall be provided at the No. 2 end of each car. The uncoupling of Married Pairs shall not require removal of the drawbar assembly from its carbody mounting.

E. The coupler length, from the center of the anchor pin to the pulling face, shall be 5 feet ± 3/16" (1.5 m ± 4.7mm). The height of the center line of the coupler, as measured from top of rail with secondary suspension at normal height and new wheels, shall be as follows:

1. Red Line: 2 feet, 7 5/8 inches (803 mm).

2. Orange Line: 2 feet, 6 1/4 inches (768 mm).

F. The Cab Car coupler and its associated equipment shall be electro-pneumatically controlled from within the cab. The Non-Cab Car coupler shall be controlled from the hostler panel.

4.02: SYSTEM DESCRIPTION & CONFIGURATION

4.02.01. Automatic Coupler

A. The No. 1 end coupler and draft gear shall consist of a mechanically hinged Tomlinson style flat faced hook-type coupler head, as well as a yoke, draft gear assembly, radial carrier and centering device.

B. The coupler head, yoke, draft gear housing and carbody mounting bracket shall be forged, fabricated or cast steel meeting the requirement specified in T 18, Materials and Workmanship. Coupler components shall be designed to withstand the loads specified in section 04.03, Performance.

C. The draft gear assembly shall absorb shock in buff (compression) and draft (tension). The assembly shall be equipped with a double acting type rubber spring, or equivalent material accepted by the Authority, capable of withstanding the loads transmitted to the vehicle from the coupler head connection to the carbody bracket.

D. The draft gear shall incorporate an emergency release mechanism, which shall release under a load by the shearing of tapered pins.

1. Alternative energy absorption and coupler deflection techniques may be required to be compatible with the energy absorption Crush Zone described in T 03.04.03, Crashworthiness. Coupler may utilize a hydraulic shock tube or alternative method to ensure that it retracts backward in a controlled manner and does not defeat the deflection and subsequent energy absorption provided by the Crush Zone, nor introduce a safety hazard by falling from the vehicle underframe.

E. The coupler head shall be supported in a horizontal position by an adjustable spring support incorporated in the yoke. Adjustment shall allow vertical motion of the head to accommodate all coupler height variations encountered in service.

F. Easily replaceable Guide pins and recessed bushings shall be provided on the coupler face to ensure alignment of the pneumatic and electrical connections between coupled cars.

G. The side-mounted electric heads shall advance after mechanical coupling and retract before mechanical uncoupling. Electric head advancement shall be initiated by the Couple Switch on the Operator's console. Retraction shall be by "Uncouple Trainline" cab controls. Air supply and /or electrical power for electric head movement of both cars shall be provided by the controlling car. Alternate arrangements may be proposed for Authority consideration.

H. Not used.

I. Automatic coupler operations shall be interlocked with the No Motion Relay.

J. All coupler wear surfaces shall be provided with easily replaceable bushings or wear plates.

K. Easily accessible manual controls shall be provided to retract electrical heads and close pneumatic trainlines on each automatic coupler. These controls shall also allow manual electrical and pneumatic coupling.

L. The automatic coupler design and functional narrative shall be submitted for Authority review and approval. [CDRL 04-01]

4.02.02. Centering Device

A. Pneumatically operated centering devices and a manually operated negating valve shall be provided on/near each automatic coupler/draft gear assembly.

B. When Married Pairs are uncoupled, the centering device shall maintain the coupler in its center position (within a tolerance of ±1.0 inches (±25.4 mm)), ensuring the coupler is correctly positioned for automatic coupling on tangent track.

C. When Married Pairs are coupled, the centering device shall automatically deactivate, permitting the coupler to move without interference.

D. When coupling on non-tangent track, the manually operated negating valve shall allow deactivation of the centering device for manual alignment of couplers.

E. The negating valve shall be located below the underframe on the right front, no further back than 12 inches (305 mm) from the anticlimber face. Alternatively, the valve may be on the front of the coupler itself, accessible from both the side and front end of the car.

4.02.03. Radial Carrier

A. The radial carrier shall be bolted to the carbody frame and vertically support the coupler at a fixed level. The mounting arrangement shall provide lateral movement of the coupler for negotiating curves. Carrier mounting bolts shall be locked and mechanically retained to prevent interference with coupler movement if loosening occurs.

B. The carrier shall be designed to allow sufficient horizontal longitudinal movement to prevent binding during buff and draft. The design shall also allow lateral movement under all variations in wheel wear, suspension deflection, track geometry and passenger loading.

C. Carrier wearing surfaces shall be protected with readily replaceable wear plates.

D. Lateral stops shall be included. The stops shall be removable to allow removal of the coupler assembly. Sufficient clearance shall be provided beyond one side of the coupler to allow it to be rotated until it clears the radial carrier.

4.02.04. Protective Cover

A. All coupler components shall be designed and fabricated to be inherently weather proof and suitable for exposure to the environment for a 30 year life. The coupler shall be equipped with covers over the electrical heads to provide additional protection from debris, rain, snow and ice. The design and arrangement shall be submitted for Authority review and approval. [CDRL 04-02]

B. The cover shall be designed to open during coupling and close upon uncoupling.

C. Cover design shall include provisions to manually open and prevent closing during maintenance and repair.

D. The design shall include provisions to allow mechanical coupling with existing cars.

4.02.05. Electrical Coupler Heads

A. Powered, retractable side mounted electric coupler heads shall be mounted on each side of the automatic coupler to provide electrical trainline coupling.

B. The contacts pins on each electric coupler shall be individually spring loaded or stationary, as required for the pin type, and be silver or gold faced, and equipped with a self-wiping feature. A damaged pin shall not prevent the remaining pins from mating.

C. The contact pins shall be mounted in an insulation block to resist the effects of the environment, including carwash detergents.

D. The block shall be equipped with a heater to prevent the accumulation of snow and ice. The heater shall be self regulating to prevent overheating, and be powered by the car's low voltage system through a circuit breaker. The heater shall energize when the electric head is below 38°F (3.3°C). Control of heaters shall be by bi-metallic thermostat. The heater and thermostat shall be removable and replaceable in 20 minutes or less. Alternate means of energizing/de-energizing heaters may be suggested for Authority review and acceptance. There will be a visual indication when the heater is activated.

E. Networking and P-wire signal trainlines shall be provided as shielded twisted pairs utilizing pin/socket type contacts on each electric coupler. Shields shall not be continuous through the coupler face. Alternate solutions for network signals may be proposed for Authority review and acceptance.

F. Contractor shall include Train Ethernet Network connections through the electric coupler head utilizing pin/socket type contacts. See T 24, Trainlines & Networks, for detailed requirements.

G. A minimum of 10 percent spare pins of each type shall be provided. Spares shall include pre-terminated wiring to the junction box and down the length of the car.

H. All pins and wiring shall be sized and designed to withstand short circuits without damage.

I. Contact block shall be labeled Left or Right, with each contact pin identified by number. Method of labeling, type and layout of pin assignments shall be approved by the Authority. [CDRL 4-03]

J. The electrical heads shall be equipped with a rubber gasket, or equivalent, that forms a tight seal between coupled cars.

K. Each electrical head assembly, including cover, shall be modular for easy removal and replacement.

L. A cover/head guard that is designed for use as a step shall be fitted over each side of the coupler. The cover shall not be connected to or make contact with the retractable heads. The cover/step shall be fabricated from diamond plate, or be provided with a similar, permanent non-slip surface. The step design shall be approved by the Authority. [CDRL 4-04]

M. The electrical head enclosures shall be rated at no less than IP 55 for water intrusion. A drain hole fitted with a split pin shall allow for drainage of condensate.

4.02.06. Coupler/Trainline Interface

A. All trainline wiring between coupler electric head and junction box will be housed in a rugged flexible conduit or neoprene sleeve. Conduit/sleeve shall be clamped along its length for support, while still allowing slack for maximum coupler rotation and pitch. Conduit material shall be in accordance with T 18, Materials & Workmanship.

B. Trainlines shall be terminated with multi-pin connectors at both the electric head and the trainline junction box.

C. Provisions for removing and replacing individual wires within the conduit/sleeve shall be included. A minimum of 10% spare wires of each size shall be included in each conduit/sleeve.

D. If the connectors for each cable are the same size, they shall be keyed differently and color coded to prevent cross connection.

E. A list of required trainlines is included in T 24, Trainlines & Networks.

4.02.07. Pneumatic Connections

A. Pneumatic coupling shall be provided as an integral part of the mechanical coupler head, to accomplish the automatic connection of the emergency brake pipe and main reservoir air lines between the cars.

B. Air connections between the coupler and the carbody shall be accomplished by flexible hoses with hose fittings and swivels.

C. All hoses in the pneumatic coupler system shall be protected and supported to prevent ballast damage, cutting, kinking, pinching, chafing and stress under all operating conditions.

D. Any unintentional uncoupling shall vent air from the emergency brake pipe of both portions of the uncoupled train to ensure an emergency brake application.

E. Intentional uncoupling shall place the cut (uncontrolled) cars into an emergency brake application. The controlled cars shall maintain normal operation.

F. Trainlined air valves shall close as part of the uncoupling process.

G. When coupling to a vehicle with no air supply, sufficient air shall be provided through the coupler trainlines to charge the disabled vehicle.

H. A means to cut out trainline pneumatic valves without uncoupling shall be provided in the cab and at the hostler panel.

I. Manual cut-out cocks shall be provided under the car, accessible from the front and side of the vehicle. The cutout cocks shall be installed within a section of pipe upstream of any flexible hoses.

J. Trainlined pneumatic design shall be submitted for authority review and approval. [CDRL 4-05]

4.02.08. No. 2 end Coupling

A. A mechanically pinned semi-permanent coupler - drawbar arrangement shall be provided at the No. 2 end of each Cab Car and Non-Cab Car.

B. The design shall be similar to the drawbar incorporated on the #3 Red Line cars. Drawings shall be submitted for Authority review and approval. [CDRL 04-06]

C. The uncoupling of a Married Pair shall not require the removal of the drawbar assembly from its carbody mounting.

D. A draft gear and an energy release device utilizing shear bolts shall be included in the design. Strength, energy absorption and deflection under load shall be identical to the automatic coupler as described in section T 04.03, Performance.

E. The pivot bearing, anchor and draft gear elements, radial carrier and shear bolts shall be the same for both the No.1 and No. 2 end couplers.

F. The Contractor shall propose a means to trainline emergency brake pipe, main reservoir air supply and jumper cables for electrical trainline connections and power feeds between shared equipment. Differing voltages shall be separated. Cables larger than #2/0 shall be terminated with either connectors or heavy duty lugs. Details of the design, including pneumatic connections, keyed quick disconnects and jumper wire connectors shall be submitted for Authority review and approval. [CDRL 04-07]

G. Manual cut-out cocks shall be provided under the car, accessible from the rear and side of the vehicle. The cutout cocks shall be in hard pipe upstream of any flexible hoses.

4.02.09. Operator Controls

A. The No. 1 end coupler controls shall be arranged so that complete automatic coupling and uncoupling operation can be performed entirely from the Operator's cab or the hostler panel. The design of the coupler controls and circuits shall eliminate the possibility of unintentional uncoupling.

B. Automatic coupler operations shall be interlocked with the No Motion Relay.

C. One momentary contact switch for coupling and two momentary contact switches for uncoupling shall be installed on the cab console and the hostler panel.

1. Once coupled to a like car, the operation of the Couple switch shall advance the electric heads, open the pneumatic trainline valves, configuring the trainlines as required for a coupled car.

2. Operation of the "Uncouple Trainline" switch shall close the pneumatic trainline valves, retract the electrical coupler heads and configure the trainlines as an end car. The Uncouple Trainline switch shall be mechanically guarded to prevent accidental activation.

3. Operation of the "Uncouple Mechanical" switch shall mechanically uncouple the cars and engage the centering devices. The "Uncouple Mechanical" switch shall be mechanically guarded and interlocked so as not to be operated prior to "Uncouple Trainline" activation.

4. Alternate arrangements may be proposed for Authority consideration.

D. Switch name plates shall be provided (See T 05, Operator's Cab, for control switch requirements). The switches shall only be active when the master controller transfer switch is energized and a no motion signal is present.

E. Controls that allow pneumatic isolation will be provided in each cab and hostler panel.

4.02.10. Electro-Pneumatic Coupler Control Unit

A. The control unit shall be located in an easily accessible area in the Cab Car and behind a locked panel in the No. 1 end of the Non-Cab Car.

B. The electro-pneumatic control unit shall house the control valves required for operation of the automatic coupler. Valves shall be fitted with electric and manual controls.

C. The unit shall control the pneumatics of the coupler, including the opening and closing of the brake pipe trainline and main reservoir trainline valves.

D. Valves shall be integrated into a manifold with clear, indelible labeling included for each device.

E. All wiring within the control unit shall feed through a single electrical cable.

F. Piping shall penetrate the floor through an air-tight, fire-proof chimney.

G. Instructions for all manual operations shall be included within the enclosure. Instructions shall be laminated to the back side of the access panel or other suitable location.

H. All devices shall be located and arranged for easy access/removal/replacement.

4.02.11. Electrical Isolation

A. Electrical isolation, circuit closing and circuit looping shall be achieved through electrical controls or by the use of a drum switch. Network connections shall not be switched by a drum switch (Refer to T 24 Trainlines & Networks) The Contractor shall provide a complete proposal detailing operation and performance, including manual operation and electrical head advancement and retraction, subject to review and approval by the Authority. [CDRL 04-08]

B. At a minimum, the following trainline connections shall always be made when the new cars are coupled, regardless of electrical head position (if a third, smaller coupler head is proposed, the contacts shall be protected from the elements with a weather proof mechanical cover):

1. Bell
2. Battery
3. Passenger Emergency Intercom (PEI)
4. Passenger Announcements
5. Door Interlock
6. At least one Train Ethernet Network path

C. If a drum switch is provided, the following requirements shall be met:

1. The drum switch shall be pneumatically operated. It shall contain normally open and normally closed contact switches sufficient to switch and loop all trainline circuits to the electrical couplers, including all spare contacts.
    a. The drum switch shall be installed integral with the Cab Car and Non-Cab Car front-end sealed trainline junction boxes.
    b. The switching contacts shall be of the self-cleaning, wiping type and shall have sufficient capacity to interrupt the maximum normal current to avoid damage by arcing.
2. The pneumatic uncoupling system and the electric drum switch shall include a means of activation in the cab in the event of a failure of the control circuit.
3. Manual activation shall also be possible from the front and the side of the car.

4.03: PERFORMANCE

4.03.01. Environmental

A. The coupler and draft gear equipment shall be sealed against, and operate successfully under all environmental conditions as specified in T 02, Vehicle Design Requirements.

B. All materials used in the fabrication of the coupler shall be corrosion resistant or protected against corrosion per T 18, Materials & Workmanship.

4.03.02. Strength

A. The coupler system shall have the strength, under emergency conditions, to allow an AW3 loaded 6-car train to pull or push an un-powered AW3 loaded 6-car train. Audible coupler "slap" shall not occur under this condition.

B. For any horizontal position of the coupler, the carrier and the car structure shall withstand, without yielding, a vertical load of 75,000 pounds (334,000 N) applied in either direction at the coupler face.

C. Under the action of compression or tension, the coupler bracket shall withstand, without yielding, a load of 165,000 pounds (734,000 N). See T 3, Carbody, for carshell testing requirements.

D. The draft gear deflection shall be between 1 1/4 inches (31.7 mm) and 1 5/8 inches (42.3 mm) under a 150,000 pound (667,233 N) load.

E. Coupling at 5 mph (8 km/ hr) shall not cause damage to any coupler or carshell components.

F. The coupler anchor shall be designed to shear at the carbody mounting bolts in the event of a severe collision. The Contractor shall estimate collision speed and crash energy required to shear the mounting bolts.

G. The Contractor shall submit a Finite Element Analysis (FEA) model and load distribution for each load case for approval by the Authority prior to performing the analyses. [CDRL 04-09]

H. FEA results shall be submitted for Authority review and approval. [CDRL 04-10]

4.03.03. Shear Pins

A. The draft gear shall be provided with shear pins that release under a load of approximately 155,000 lbf (689,474 N). After release, each draft gear shall have sufficient free travel to permit opposing anticlimbers to engage.

4.03.04. Maximum Coupler Swing

A. The maximum coupler swing shall be sufficient to accommodate a 110 foot (33.5 m) radius horizontal curve.

4.03.05. Coupler Gathering

A. Couplers shall have sufficient gathering range to accommodate a vertical displacement of ± 3 3/4 inches (95 mm) and a lateral displacement of ± 3 3/4 inches (95 mm) between mating couplers with up to 12.0 degrees of rotational mismatch.

B. The horizontal and vertical pivot angles shall be up to ± 29.5 degrees and ± 10 degrees respectively.

C. The yoke shall permit the coupler to rotate sufficiently (up to ± 6 degrees) to accommodate the worst case combination of static and dynamic spring deflection, suspension failure, super elevation, dynamic body roll and track cross level.

4.03.06. Manual Release

A. The force required at the manual lever for manual uncoupling shall not exceed 70 pounds (311 N).

4.03.07. Manual Positioning

A. The force required for manual positioning shall not exceed 85 pounds (378 N) at the coupler head.

4.04: RELIABILITY

4.04.01. Mechanical Coupler Reliability

A. Mean Distance Between Component Failure on the mechanical portion of the Coupler system shall be no less than 1,000,000 miles (1,609,344 km).

4.04.02. Electrical Coupler Component Reliability

A. Mean Distance Between Component Failure of the electrical portion of the Coupler system shall be no less than 500,000 miles (480,000 km) not including electrical coupler pins. Coupler pin reliability is included in T 24, Trainlines and Networks.

4.05: MAINTAINABILITY

4.05.01. Shear Pin Replacement

A. Shear pins shall be easily accessible and replaceable. Pin removal and replacement shall require not longer than 30 minutes.

4.05.02. Coupler Pin Replacement

A. Contact pins shall be screw in type and easily removable and replaceable from the coupler pulling face. Contact type shall be interchangeable.

4.06: SAFETY

4.06.01. General

A. Automatic coupler operations shall be interlocked with the No Motion Relay.

B. The uncouple solenoid valves and associated circuits shall be wired and be interlocked to prevent unintentional operation of the uncoupling system.

C. The sequence of the two cab console uncoupling switches shall be interlocked so that the pneumatic and electric connections will be disconnected before mechanical uncoupling. When the first uncoupling switch is energized, the un-powered portion of the train shall be placed in emergency brake.

D. The second uncoupling switch (mechanical uncoupling switch) shall include provisions to protect against accidental activation. The design shall be submitted and approved by the Authority. [CDRL 4-11]

E. Braided safety ground straps shall be provided between the coupler and a dedicated ground boss on the carshell.

F. A locking pin or similar device shall be provided for locking of coupler hooks when pushing or pulling a dead car.

4.07: COMPATIBILITY

4.07.01. Red Line Compatibility

A. The coupler equipment shall be mechanically compatible with the existing #2 and #3 Red Line cars.

4.07.02. Orange Line Compatibility

A. The coupler equipment shall be mechanically compatible with the existing #12 Orange Line cars.

4.07.03. Red and Orange Line Inter-Compatibility

A. Components used on the Red and Orange Line shall be identical, to the maximum extent practical.

4.08: INSPECTION

4.08.01. Cast and Fabricated Component Inspections

A. Coupler and draft gear castings and welds shall be subject to radiographic and dimensional inspection to assure that the casting process is producing castings of the required internal quality, wall thickness and overall dimensions.

B. Prior to stress relief heat treatment and normal surface preparation, the first coupler and draft gear castings shall be subjected to a 100% radiographic inspection. If there are any defects in the first castings, the manufacturer shall make such changes in production as are deemed necessary to rectify the cause of any defects. The second produced castings shall then be inspected in a similar manner to the previous castings in critical areas and in any areas that were noted as being deficient on the previous castings. The manufacturer shall continue with this process until two consecutive castings are produced that meet requirements and are free of defects.

C. Radiographic inspection shall be conducted per ASTM E 94 and ASTM E 142. Radiographs shall be evaluated in accordance with ASTM E 446. The permissible severity levels of defects in the castings shall be Classes 2 and 3, or better in critical areas and Class 5 or better for gas porosity, inclusions and shrinkage as indicated on a drawing to be furnished by the coupler manufacturer. Cracks and hot tears shall not be permitted.

D. After the manufacturer has demonstrated a satisfactory production process, the remaining coupler and draft gear castings shall be inspected using magnetic particle and dimensional inspection.

E. The overall quality of each casting shall be assured by careful visual and magnetic particle inspections. Just prior to stress relief heat treatment, the entire surface of the coupler and draft gears shall be shot blasted and inspected by the dry powder magnetic particle method per ASTM E 709. Criteria for acceptance/rejection for surface indications on the castings shall be in accordance with ASTM E 125. There shall be no cracks permitted.

4.09: QUALIFICATION TESTING

4.09.01. General

A. The testing requirements are broken out into tests conducted on the individual components and tests conducted on the Pilot Cars. Component tests are listed in this section and Pilot Car tests are included in T 20, Testing & Validation.

B. Procedures for the tests listed in this section shall be submitted for Authority review and approval. [CDRL 4-12]

C. Test Reports shall be submitted for Authority review and approval. First Article Inspection (FAI) acceptance shall be subject to successful completion of the tests. [CDRL 4-13]

4.09.02. Static Design Load Test

A. 150,000 lbf (667,233 N) shall be applied to the coupler face. Coupler shall deflect between1 1/4 inches (31.7 mm) and 1 5/8 inches (42.3 mm). There shall be no visual permanent deformation, fractures or cracks in any component.

4.09.03. Shear Pin Test

A. Compression forces shall be increased until the shear pins release. Testing shall ensure that the pins release at approximately 155,000 lbf (689,474 N) and that the coupler moves back at least 3 inches.

4.09.04. Shear Pin Removal Test

A. The release mechanism shall be intentionally activated to determine that it functions as intended and that shear pins can be readily identified, removed and replaced. The test shall include both partially sheared pins and completely sheared pins.

4.09.05. Gathering Range Test

A. Two completely assembled front end mechanical couplers, but excluding the electric couplers, shall be mounted in a fixture and tested to ensure compliance with T

04.03.05, Coupler Gathering. In addition, six degrees of rotation of each of the coupler heads shall be incorporated in the test.

B. A computer model including all movement constraints may be used instead of above mentioned mock-up.

4.09.06. Lateral Force Test

A. Tests shall be made on the fixture described above to ensure that the lateral forces required to position the coupler are within the limits specified in section 4.03.07A, Manual Positioning.

4.09.07. Manual Lever Force Test

A. Tests shall be made on the fixture described above to determine that the forces required to manually uncouple are within the limits specified in section 4.03.06A, Manual Release.

4.09.08. Maximum Coupler Swing

A. The coupler shall be rotated to represent worst case rotation on a 110 foot (33.5 m) radius horizontal curve. The coupler shall not engage the coupler stops.

4.09.09. Centering Device Test

A. Tests shall be conducted on the test fixture described above to determine that the automatic centering device functions properly and centers the coupler to within ±1 inch (25 mm) of the carbody centerline.

4.09.10. Electric Coupler Water Test.

A. The coupler shall be tested to confirm that the design of the cover will minimize the ingress of water when the coupler is in the lead position of the train and that the design of the sealing arrangement will eliminate water penetration when the equipment is coupled in the middle of a train. The rate and method of water spray to be applied shall be as stipulated for the vehicle water test specified in T 20, Testing & Validation. Water testing shall also simulate the effect of water impingement as a result of wheel spray.

B. The test shall be repeated on the No. 2 end draw bar and jumper cables.

4.09.11. Electric Coupler Ice and Snow Test

A. The Electric Coupler Water Test shall be repeated in an ice and snow environment to confirm the functionality and effectiveness of the coupler heaters.

4.09.12. Coupler Cable Life Cycle Test

A. The coupler connecting cables and intercar jumper cables shall be mocked-up as installed on the vehicle and given a 100,000 cycle flexing test. The test shall simulate vehicle worst case conditions for vertical and horizontal curves and minimum turnouts. After 100,000 cycles of flexing, the cables shall exhibit no evidence of wear or failure. This shall be verified by disassembly and inspection of each cable and its components. No insulation wear or rupture shall be permitted and no wire strands shall be broken.

4.10: CDRL ITEMS REFERENCED

CDRL 04-01, “Automatic Coupler Design”, (Ref: T 04.02.01.L)

CDRL 04-02, “Coupler Cover”, (Ref: T 04.02.04.A)

CDRL 04-03, “Pin Assignments and Contact Block Marking Method”, (Ref: T 04.02.05.I)

CDRL 04-04, “Coupler Step”, (Ref: T0 4.02.05.L)

CDRL 04-05, “Trainlined Pneumatic Design”, (Ref: T 04.02.07.J)

CDRL 04-06, “No. 2 End Coupler and Draft Gear”, (Ref: T 04.02.08.B)

CDRL 04-07, “No. 2 End Trainline Cables and Connectors”, (Ref: T 04.02.08.F)

CDRL 04-08, “Electrical Isolation Functional/Technical Description”, (Ref: T 04.02.11.A)

CDRL 04-09, “Coupler FEA Model and Load Cases”, (Ref: T 04.03.02.G)

CDRL 04-10, “Coupler FEA Strength Analysis”, (Ref: T 04.03.02.H)

CDRL 04-11, “Mechanical Uncoupling Switch Protection”, (Ref: T 04.06.01.D)

CDRL 04-12, “Coupler Test Procedures”, (Ref: T 04.09.01.B)

CDRL 04-13, “Coupler Test Reports”, (Ref: T 04.09.01.C)

4.11: REFERENCES

4.11.01. Standard References

ASTM E 94, Standard Guide for Radiographic Examination.

ASTM E 125, Standard Reference Photographs for Magnetic Particle Indications on Ferrous Castings

ASTM E 142, Standard Method for Controlling Quality of Radiographic Testing

ASTM E 446, Standard Reference Radiographs for Steel Castings Up to 2 in. (51 mm) in Thickness.

ASTM E 709, Standard Guide for Magnetic Particle Examination

4.11.02. Technical Specification Cross References

T 2, Vehicle Design Requirements
T 3, Carbody
T 5, Operator's Cab
T 12, Friction Brakes & Pneumatic System
T 18, Materials and Workmanship
T 19, Quality Assurance
T 20, Testing and Validation
T 24, Trainlines and Networks

PART T 05.00
OPERATOR'S CAB

Table of Contents

5.01: GENERAL

5.01.01. System Description & Configuration

A. The Operator's cab shall be a full width design that provides a safe, ergonomic, Operator-friendly environment. Ergonomic studies shall be performed that include investigations for Operator's size range of; 5% female to 95% male, and include consideration of Military Standard (MIL-STD) 1472F, Society of Automotive Engineering (SAE) J1050 and SAE J287. [CDRL 05-01]

B. All items in this section of the specification will be evaluated in the Operator's cab mock up. Refer to T 01, General, for a comprehensive list of items that shall be included in the mock up.

C. Married Pairs shall include a full cab in one car (Cab Car) and a hostler panel in the No. 1 end wall of the second car (Non-Cab Car). All control equipment for the Married Pair shall reside in the Cab Car, to the maximum extent practical.

D. The full cab shall have the ability to operate in two basic modes; full control for the Operator to operate the train (propulsion, braking, etc.), and a second mode for the attendant to monitor and control the passenger doors. Any cab may be configured for door control.

E. The Red and Orange Lines are normally operated in train-sets of 6 cars (3 Married Pairs). Cab cars will be arranged at extreme ends of the train-set to allow operation in both directions.

5.02: CAB GENERAL ARRANGEMENT AND EXTERIOR COMPONENTS

5.02.01. Cab Partition Wall

A. The cab shall be separated from the passenger area by a full height, full width transverse partition wall.

B. The partition wall shall be manufactured from aluminum or stainless steel sheets heat bonded to an aluminum or stainless steel honeycomb core. High Pressure Decorative Laminate exterior skins shall be included in the heat bonding process. The color and texture shall be determined during design reviews.

C. The wall shall be supported and fastened to carbody structure along both sides. Upper and lower edges shall be provided with angle brackets, or equivalent, that are bolted into inserts or tapping plates provided in the floor, sidewall and ceiling panels.

D. All edges of the panel shall be fitted with extruded or formed sections that enclose the honeycomb and prevent the ingress of moisture.

E. Methods to avoid noise (squeaking, rattling) created by panels during operation shall be applied to the entire perimeter of the partition wall.

F. Left and right sides of the partition wall shall be fitted with windows sized and aligned to match the vehicle side windows. The glazing shall be 1/4 inch (6.4 mm) laminated safety glass. A graduated tint may be proposed for glare reduction.

G. The window shall be supported in the wall by a continuous neoprene window rubber. A window film shall be applied that allows the operator to look into the passenger compartment while blocking the view from the passenger compartment into the cab.

H. All fasteners threaded into the partition shall utilize threaded inserts or tapping plates.

I. The partition shall be designed to resist a load of 200 lbs (890 N) applied to a 6 in x 6 in (152 mm x 152 mm) surface area with no permanent deformation.

J. The partition shall be designed to resist a load of 500 lbs (2,224 N) applied to a 24 in x 24 in (610 mm x 610 mm) surface area with no permanent deformation.

5.02.02. Cab Door

A. The cab door shall be constructed of the same material as the cab partition wall and sealed around its entire perimeter with aluminum or stainless steel formed sections.

B. The door shall be supported on its left side (guard side) by a full length stainless steel hinge and arranged so that the door swings into the cab when opened.

C. The cab door shall be fitted with a rugged lock and latch as manufactured from JL Howard, or equivalent. The lock shall open from the passenger side with the Authority crew key. The lock shall be designed to open from the cab side by rotating a heavy duty handle.

D. The lock shall be configured to automatically release and remain unlocked when the adjacent passenger emergency stop is pulled.

E. The design of the door shall include a louvered, sight-tight grille to provide a return path for cab supply air.

F. The gap provided around the entire perimeter of the door shall be no greater than 1/8 inch (3.2 mm).

G. The door shall be fitted with a bumper bolted to the lower edge of the door and a hold open device that automatically latches when the door is fully opened.

H. All fasteners threaded into the door shall utilize threaded inserts or tapping plates.

I. The door shall be designed to resist a load of 200 lbs (890 N) applied to a 6 in x 6 in (152 mm x 152 mm) surface area with no permanent deformation.

J. The door shall be designed to resist a load of 500 lbs (2,224 N) applied to a 24 in x 24 in (610 mm x 610 mm) surface area with no permanent deformation.

5.02.03. Cab Interior surfaces

A. The cab ceiling, corner hatches, sidewall liners and flooring shall be an aesthetically seamless continuation from the passenger area. Coving shall be provided along the floor/sidewall interface.

B. All fasteners threaded into any interior surface shall utilize threaded inserts or tapping plates. Neither self-tapping screws nor tapered thread screws shall be used.

C. Cable passageways through the floor shall be completely fire-sealed and shall be included in the floor fire test described in T 03, Carbody.

5.02.04. Equipment Enclosures

A. All equipment within the cab, except for items provided for safety or regular train operation, shall be housed in equipment enclosures.

B. All enclosures shall be provided with hinged access panels for equipment maintenance and troubleshooting. Access covers will be of sufficient number and size to allow direct access to every component in the enclosure without requiring the removal of other components or any part of the enclosure.

C. Enclosure material shall be durable and aesthetically pleasing. Enclosures shall be arranged such that the Operator has a clear, comfortable working area and full access to side windows, electrical switches and all other controls within the cab. Contractor shall propose design approaches, space requirements and equipment layouts in the form of Cab General Arrangement drawings for Authority review and approval. [CDRL-05-02]

5.02.05. Cab Side Windows

A. Each side of the cab shall be fitted with a heavy duty sliding window. Window shall be designed to allow one full height portion of the window to slide horizontally in front of the other. The sliding portion shall be determined during the mock up.

B. The window shall be enclosed in a stainless steel or anodized aluminum frame bolted into threaded inserts or tapping plates provided on the sidewall of the carshell. The fixed portion of the glass shall be bonded to the frame. The sliding portion of the window shall slide in a track that is an integral part of the frame.

C. The entire perimeter of the sliding section shall be sufficiently weather-stripped to withstand the environmental criteria of T 02 as well as pass through the Authority's car wash and remain water-tight. Drain holes shall direct water accumulated in the track towards the outside of the car.

D. The sliding portion of the window shall be equipped with a lever type latch that locks the window in the closed position. The lever, latch and lock shall be subject to Authority approval. A sample of the complete window assembly shall be provided during design review. [CDRL-05-14]

E. Cab glazing shall be FRA type 2, clear laminated safety glass.

F. In the fully opened position, a minimum clear opening width of 16 inches shall be provided. Ergonomic studies shall be conducted to ensure clear opening is optimally located for an Operator leaning out of the window. [CDRL 05-03]

5.02.06. Windshield

A. Each side of the cab shall be fitted with a clear, FRA type 1 windshield.

B. The windshield shall be designed to maximize the field of view. All Operators, including 5th percentile females through 95th percentile males, shall be able to view the coupler head from a standing position at the cab console. In the seated position, the operator shall be capable of detecting a 24 inch (610 mm) tall object on the track centerline, 8 feet (2.4 m) away from the anti-climber. [CDRL-05-04]

C. The windshield shall be supported and sealed by a frame installed from the vehicle exterior. The frame and windshield shall be fastened to threaded inserts in the front mask. The windshield and frame shall be suitably gasketed to be water-tight without the use of sealant.

D. The Contractor shall propose a design approach to minimize interior reflections that may distract the Operator. Anti-reflective film on the windshields, polarized film on the partition windows, tinted lighting or similar approach shall be provided for Authority review and approval. [CDRL-05-05] Interior reflections shall be reviewed during the cab mock up.

E. Left and right windshields shall incorporate a micro element heater powered from 120 VAC. Alternative heater designs shall be subject to Authority review and acceptance.

F. A 3-position momentary rocker switch on the cab console shall control the Operator's windshield heater. The switch shall incorporate both a momentary ON and a momentary OFF position. Selecting ON or OFF shall energize or de-energize the four windshields on the extreme ends of the train-set.

G. The windshield heater shall clear a minimum of 75% of the windshield surface area. Un-cleared areas shall be limited to a 2 inch (51 mm) band around the perimeter of the glass. Watt density shall be selected to clear a 1/32 inch (1 mm) layer of ice from the windshield in 15 minutes or less under winter conditions listed in T 07.07.02B, Design Conditions.

H. The windshield heaters shall de-energize along with the HVAC units, 15 minutes after the transfer switch key is removed.

I. Over-temperature protection shall be fail-safe. Power shall be disconnected from the windshield heater in the event of an over-temperature condition and require the Operator or Attendant to manually reset the over-temperature device to re-energize the heater. The reset device shall be accessible by the Operator from a seated position. The illuminated Heated Windshields ON Indicator on the cab console shall be extinguished in the event of an over-temperature fault.

J. Over-temperature shall not result from continuous operation at any ambient temperature below 60°F (16°C).

5.02.07. Windshield Wipers

A. Windshield wipers shall be installed on the Operator's (right side) windshield in each cab.

B. The wiper motor shall be powered from the DC Low Voltage Distribution Network and be easily accessible from the interior of the cab. A hatch or access cover shall open to allow removal and replacement of the motor.

C. Speed shall be controlled by a switch on the cab console. Positions shall include Off, Low, High and adjustable Intermittent. Adjustable intermittent shall provide a range of time delays between wiper cycles.

D. Wiper arm shall be fabricated from corrosion resistant material or suitably protected. Arm linkage shall be designed to ensure blade remains vertical throughout its sweep.

E. The parked position of the wiper blade shall be the extreme right or left side of the windshield.

F. Wiper blades shall sweep a minimum of 75% of the windshield surface.

G. Wiper blades shall be replaceable in less than 10 minutes.

5.02.08. Windshield Washer

A. Not used.

B. Washer controls may be incorporated into the wiper controls or controlled separately.

C. Spray nozzles shall be located above the windshield and shall not be attached to the wiper arm. They shall be arranged to spray a fine mist over the blade swept area.

D. A washer fluid tank shall be a minimum of 3 gallons (11.4 liters) and shall be fabricated from a corrosion resistant material. The tanks shall be easily accessible from the exterior of the cab.

E. The filler cap shall be fitted with a lanyard attached to the tank. Graduated lines visible from the exterior of the tank shall indicate fill level.

5.02.09. Pneumatic Horn

A. A dual-trumpet transit quality air horn shall be located under the No. 1 end of the Cab and Non-Cab cars. The horn shall be powered from the cars air system. Manual cut-out valves shall be provided in the cab and hostler area equipment locker.

B. The horn magnet valve shall be energized from push button labeled "Horn". Pushbuttons shall be located on the cab console and the hostler panel.

C. At a distance of 100 feet (30.5 m) in front of the train, on open air track, the horn shall have a minimum sound pressure of 95 dBA. The sound level shall not exceed 98 dBA.

D. The faces of the horns shall be fitted with a perforated guard or mesh that prevents snow from accumulating in the horn trumpets, while not significantly affecting sound output.

5.03: CAB CONTROLS

5.03.01. General

A. The cab control layout shall be reviewed and approved through iterative reviews of the Cab mock up. Features of the arrangement that shall be specifically investigated include:

1. Ergonomic layout of controls in a logical manner.
2. Robust surface finishes that resist wear, scratches and Ultra-Violet (UV) degradation.
3. Clear, legible control labels that will not deteriorate over time and are highly visible in all lighting conditions.
4. Ease of control removal and replacement.

5.03.02. Master Controller Panel

A. The Master Controller panel shall be located to the right of the Operator to allow control of the train by the right hand.

1. The Master Controller shall control propulsion and braking of the entire train-set based on the position of the slide handle. See T 15, ATP & ASR, T 02, Vehicle Design Requirements, and T 24, Trainlines & Networks, for detailed requirements.
2. There shall be 6 marked positions on the Master Controller slide handle guide. Starting from the rear, they shall be: Store, Emergency, Full Service (F.S.) Brake, Min Brake, Coast, Min Power and Max Power.
3. There shall be an over-travel button to allow the Master Controller handle to move to the Store position. Store position shall be available only when the direction switch is set to STORE.
4. There shall be detents at the Full Service Brake and the Coast positions of the Master Controller Handle.
5. Movement of the Master Controller between Min Power and Max Power shall cause a linear increase in tractive effort. Movement of the Master Controller from Min Brake to Full Service Brake shall cause a linear increase in braking effort.

6. The Master Controller shall generate two signals to indicate power or brake request: a level value or signal that indicates the degree of power or brake and a discrete signal which indicates mode of operation (power or brake). Alternate concepts for reliable and fail safe design may be proposed for Authority approval.

7. The Master Controller design shall utilize the minimum number of limit switches feasible.

8. The Master Controller shall incorporate a dead man feature. The dead man feature may be a spring loaded handle or similar device. This feature shall initiate an irretrievable emergency brake application if the Operator releases the Master Controller handle under the following conditions:

   a. The Master controller is in any position other than STORE or Full Service Brake.

   b. Any time the Master controller is in the Full Service Brake position, but the train is moving (except when controlled by the "Inching Switch" described in T 05.03.02.E below).

9. The dead man feature shall be designed with Operator comfort and the elimination of arm/hand fatigue in mind. Contractor shall propose alternatives for Authority review and selection. [CDRL 05-06]

B. A two position (ON-OFF) transfer switch operated by a dedicated cab control key shall be provided on the Master Controller Panel. The key shall be identical to the #5 Blue Line transfer switch key.

1. Placing the switch in the ON position shall unlock the Master Controller, energize the HVAC units and enable the cab controls to provide full train-set control to the Operator.

2. Once a Lead cab is selected and its transfer switch is placed in the ON position, all other Master Controllers and transfer switches (including hostler panel) within the train-set shall be disabled.

3. The Transfer Switch shall not move to the OFF position unless the Master Controller handle and the reverser switch are both in the STORE position. The key shall only be removable once the switch is in the OFF position.

4. When the transfer switch is turned OFF, train propulsion control from that cab shall be locked out. See T 24, Trainlines & Networks for further details. The Low Voltage Power Supply (LVPS) and auxiliary inverter, door operators, all interior lighting and all cab lighting shall remain on as long as the 600 VDC is available.

   a. All interior lighting controls in all cabs shall be enabled at all times, regardless of the transfer switch position.

C. The master controller shall include a 3 position direction switch. Positions shall include FORWARD-REVERSE-STORE.

1. The direction switch can move between FORWARD and REVERSE only when the Master Controller handle is in the FULL SERVICE BRAKE, EMERGENCY or STORE positions.

2. Propulsion and braking control shall only be available in the Forward and Reverse Positions.

D. The panel shall be fitted with a padded arm rest to minimize Operator fatigue.

E. A 3 position, (Power-Coast-Brake) "Inching" switch shall be located on the back side of the Operator's console, in front of the windshield. The switch shall be accessible by 5th percentile female through 95th percentile male Operators standing in front of the windshield.

1. With the transfer switch ON, a direction selected, and the Master Controller in Full Service Brake position, the Inching Switch may be enabled to control the vehicle.

a. The power position shall release full service brakes and provide no more than 20% of tractive effort.

b. Selecting coast shall remove power.

c. Releasing the Inching Switch shall reapply the full service brake.

2. The switch shall be clearly and indelibly labeled and guarded with a cover to prevent inadvertent actuation.

3. A fail safe Inching Switch enabling concept shall be proposed by the Contractor for review and approval by the Authority. [CDRL 05-07]

5.03.03. Operator's Console Switches

A. In addition to the Master Controller panel, the following switches and controls shall be located on the Operator's console. Layout of switches shall be proposed by the Contractor for Authority review and discussion at the mock up.

Switch	**Switch Type**
Wiper (Low/Off/Hi/Adjustable Intermittent)	Contractor to propose an appropriate switch for functionality
Wash/Wipe	Momentary Rocker Switch (may be integrated with wiper switch)
Horn	Momentary Mushroom Pushbutton
Emergency Stop	Mushroom Pushbutton
Headlights (Off-Low-High)	Rocker Switch (Off position is momentary only)
Windshield Heater (On-Off)	Momentary Rocker Switch
Interior Lights (On-Off)	Momentary Rocker Switch
Cab Lights	Rocker Switch
Aux. Cab Lights (including lighting within equipment enclosures)	Rocker Switch
Cab Heater Fan (Off-Low-High)	Rocker Switch
Cab Heater Thermostat	Potentiometer
No Motion Reset	Momentary Rocker Switch
Sleet Scraper	Rocker Switch
Snow Brake	Rocker Switch
Couple	Momentary Rocker Switch
Uncouple Trainline	Momentary Rocker Switch With Guard
Uncouple Mechanical	Momentary Rocker Switch With Guard
Bell	Momentary Mushroom Pushbutton
Lamp Test	Momentary Rocker Switch
Console Lamp Dim	Potentiometer
Cab Ceiling Fan (If Required)	Rocker Switch
PA Talk	Momentary Push Button
Train Shut-Down	Momentary Rocker Switch With Guard
Emergency HVAC Shut-Down	Rocker Switch With Guard
Security Alert	Unlabeled Momentary Pushbutton
Passenger Emergency Stop Reset	Momentary Rocker Switch

Table 05-1 Operator's Console Switches

B. Labeling of switches shall be via metal etching in high contrasting colors or alternate means subject to Authority review and acceptance. Adhesive labels or silk screening shall not be accepted.

C. Console panels shall be fabricated from corrosion proof material and finished with a heavy duty surface treatment that resists scratches, wear and the effects of UV exposure.

D. Design consideration shall be given to prevent damage from spills.

E. Switches shall be easily accessible for repair and replacement. The time required to access, remove and replace any console switch shall be 10 minutes or less.

5.03.04. Bypass/Cutout Panel

A. The following switches and controls shall be located on the Bypass/Cutout Panel in the cab. Layout of switches shall be proposed by the Contractor for Authority review and discussion at the mock up.

Cutout/Bypass Switch	**Switch Type**
Truck One Propulsion Cutout	Toggle
Truck Two Propulsion Cutout	Toggle
Non Cab Car Truck One Propulsion Cutout	Toggle
Non Cab Car Truck Two Propulsion Cutout	Toggle
Door Interlock Bypass	Toggle, Sealed
No Motion Bypass Cab Car	Toggle, Sealed
No Motion Bypass Non-Cab Car	Toggle, Sealed
Regeneration Cutout	Toggle
Door Control Isolation Cab Car	Toggle
Door Control Isolation Non-Cab Car	Toggle
Air Compressor Cut-Out	Toggle, Sealed
Brake Interlock Bypass	Toggle, Sealed
Aux. Inverter Cab Car	Toggle, Sealed
Aux. Inverter Non-Cab Car	Toggle, Sealed
LVPS Isolation Cab Car	Toggle, Sealed
LVPS Isolation Non-Cab Car	Toggle, Sealed
Lighting Cutout - Cab Car	Toggle
Lighting Cutout – Non-Cab Car	Toggle

Cutout/Bypass Switch	Switch Type
HVAC Cutout - Cab Car	Toggle, Sealed
HVAC Cutout - Non-Cab Car	Toggle, Sealed
Floor Heat Cutout - Cab Car	Toggle, Sealed
Floor Heat Cutout - Non-Cab Car	Toggle, Sealed

Table 05-2 Cutout/Bypass Switches

B. The Contractor shall propose switch types and sealing methods for Authority consideration.

5.03.05. Illuminated Console Indicators

A. The following Light Emitting Diode (LED) indicators shall be provided on the Operator's console and the hostler panel, as applicable. Layout of the indicators shall be proposed by the Contractor for Authority review and discussion at the mock up.

Indicator	Color	Location
Door Interlock Bypass	Red	Cab and Hostler Panel
No Motion Bypass	Yellow	Cab and Hostler Panel
Regen Cutout	Yellow	Cab
Sleet Scraper On	Yellow	Cab
Snow Brake On	Yellow	Cab
Parking Brake On	Red	Cab and Hostler Panel
Heated Windshields On	Yellow	Cab and Hostler Panel
Brake Fault	Red	Cab and Hostler Panel
Doors Summary Loop	Green	Cab and Hostler Panel
Passenger Emergency Stop	Red	Cab

Table 05-3 Illuminated Console Indicators

B. Indicators shall illuminate when the Push to Test button on the cab console is depressed.

5.03.06. Circuit Breaker Panels

A. Separate circuit breaker panels for 120/230 VAC and Low Voltage DC shall be provided in an easily accessible location within the cab. Layout of switches shall be proposed by the Contractor for Authority review and acceptance at the mock up.

B. 600 volt breakers shall be located in equipment boxes underneath the car, easily accessible from the side of the vehicle. Refer to T 09, Auxiliary Electric Equipment, for additional details.

C. Refer to T 18.28.03, Circuit Breakers, for technical requirements.

5.03.07. Passenger Door Controls

A. Each cab sidewall shall include a panel for door control and Operator/Attendant communication. Door control panel shall be easily accessible by personnel either leaning out the cab side window or viewing the Closed-Circuit Television (CCTV) monitors on station platforms.

1. Also included in the Door control panel are pushbuttons for deploying and retracting the bridging mechanism. Refer to T 06.02.10, Gap Mitigation Devices/Bridging Mechanism. (OPTION)

2. Also included in the Door control panel are pushbuttons for enabling door opening by passenger push buttons located at each doorway. Refer to T 06.03.03, Internal and External Passenger Door Open Buttons. (OPTION)

B. The panel on the left sidewall shall control the doors on the left side of the train and the panel on the right side shall control right side doors.

C. Door pushbuttons shall be a recessed type that precludes accidental activation and shall be LED lighted. Refer to T 06, Passenger Doors & Controls, for detail.

D. Designs for the style and layout of pushbuttons on the door control panel shall be proposed and samples be provided by the Contractor for discussion with the Authority during design reviews.

E. A momentary pushbutton switch shall be included with the door controls for operation of a buzzer, used for communication between Attendant and Operator.

F. The pushbutton shall energize the buzzer trainline and power all buzzers in the train-set. Depressing the pushbutton in any cab setup for door control shall energize buzzers in all cabs.

G. Passenger door controls and buzzers are activated on any cab in the train-set with the Door Setup Switch in the ON position.

1. The location of the 3-position (ON-OFF-THRU) rotary Door Setup Switch shall be determined during design reviews. Refer to T 06, Passenger Doors and Controls, for switch functionality.

2. Door control design shall preclude simultaneous control of any doors by more than one cab, regardless of Door Setup Switch position. An amber LED indicator light shall be installed on the door control panel to indicate incorrect door operation on the train-set. In addition, the door control circuit breaker shall trip after a preset period of time (adjustable, originally set to 15 seconds) as a result of

an attempt to simultaneously control any door from 2 cabs. The VMD shall indicate the Door Setup Switch positions of all cabs in the train-set.

3. Alternative arrangements that allow door control from any cab may be proposed during design reviews, for Authority review and acceptance.

H. The door control panel shall include a red LED indicator light, designed and suitably labeled to indicate a No-Motion failure.

I. Refer to T 06, Passenger Doors and Controls, for additional requirements.

5.03.08. Signal Bell

A. A signal bell shall be installed in each cab. The bell shall be controlled from a momentary mushroom pushbutton on the cab console. The bell is primarily used for Operator communication to Attendant.

B. The pushbutton shall energize the bell trainline and power all bells in the train-set. Depressing the pushbutton in any cab shall energize bells in all cabs.

C. The bell shall be Faraday model 247-3, 3 inch (76 mm) gong powered from DC Low Voltage Distribution Network. Alternate makes/models may be proposed for Authority review and acceptance.

5.03.09. Miscellaneous Audible Alarms

A. In addition to the buzzer and bell, each of the following shall have a distinct enunciation:

1. Wayside Worker Warning System alarm
2. Overspeed alarm
3. Smoke alarm
4. Passenger Emergency Intercom chime
5. Crew Intercom chime
6. Bridgeplate request chime (OPTION)
7. Deadman

B. The Contractor shall propose audible alarm tones and sound level, subject to Authority review and approval. [CDRL 05-08]

5.03.10. VMS Display Screen

A. The Vehicle Monitoring Display (VMD) shall be a multi-color LCD, 10.4" (264 mm) minimum diagonal length screen of robust design and installation.

B. The VMD shall be centrally located and is intended to be the primary source of information for the Operator. The screen shall be fully visible under bright sunlight. Verification of suitable sunlight protection will be determined on the mock up.

C. The VMD shall be fitted with ruggedized connectors to allow removal and replacement in less than 10 minutes.

D. Refer to T 16, Vehicle Monitoring System, for detailed requirements.

5.03.11. CCTV Display Screen (OPTION)

A. The CCTV display screen shall be a multi-color LCD, 12.1" (307 mm) minimum diagonal length. The screen shall be robust in design and installation.

B. The screen shall have limited Operator control. When a cab is configured as the lead cab or setup for door control, the screen within that cab shall automatically energize when a call is received from any Passenger Emergency Intercom (PEI), Passenger Emergency Stop, or other system set up to activate the CCTV system within the train-set. The camera view that captures the PEI and surrounding area shall be displayed.

C. The Operator's screen shall be activated only after the train comes to a stop.

D. Not used

E. The screen shall be designed to allow removal and replacement in less than 10 minutes.

F. The screen shall be fully visible under bright sunlight. Verification of suitable sunlight protection will be determined on the mock up.

G. Refer to T 13 Communications & Passenger Information System, for interfaces and control.

5.03.12. Aspect Display Unit

A. The Aspect Display Unit (ADU) shall be installed in the cab as described in T 15.02.07, Aspect Display Unit (ADU).

B. Automatic Train Protection and Automatic Speed Regulation (ATP/ASR) controls shall be included in the ADU.

C. The Manual Release Switch (MRS) for the ATP/ASR shall be installed at a distance from the ADU to ensure Operators are required to leave the cab seat to engage the release. Location and switch type shall be determined during the mock up.

D. A 2-position emergency bypass switch shall be located in the cab in a locked enclosure. Enclosure shall NOT be accessible from the Operator's seat. The lock shall be opened with Authority crew key.

5.03.13. Duplex Air Gauges

A. Transit grade, heavy duty duplex air gauges shall be provided adjacent to the cab console and hostler panel.

B. Gauges shall be properly labeled and shall display emergency brake pipe pressure, main reservoir pressure, truck #1 and truck #2 brake cylinder pressures.

5.03.14. Air Lines

A. Cab pneumatic feeds shall be incorporated into a manifold located in an enclosure under the Operator's console, or other suitable location in the cab. The manifold will include permanent labels and test fittings for each system, including but not limited to, main reservoir, emergency brake pipe, truck 1 and truck 2 brakes.

B. Cutout cocks located in the cab include horn, trip cock, truck No.1 brakes, truck No. 2 brakes and truck No. 1 secondary suspension.

C. The truck No. 2 secondary suspension cutout cock shall be located in the passenger area behind a locked access panel.

D. The arrangement and location of the manifold and the cutout cocks shall be reviewed and approved by the Authority. [CDRL 05-09]

5.03.15. Communications Control Panel

A. A Communications Control Panel (CCP) shall be mounted adjacent to the console. The panel shall be designed to interface with the Passenger Emergency Intercoms (PEIs), crew intercom system and train radio.

B. A Phone type handset with integrated earpiece speaker and microphone shall be provided for Operator communication with PEI units or other cabs in the train-set, as well as over the train radio. The handset shall be a heavy-duty component designed to withstand a 30 year life.

C. Two cab speakers shall be installed in the ceiling.

D. All components included with the CCP shall be modular in design and provided with connectors to allow quick and easy troubleshooting and component replacement.

E. Hand held microphones shall be provided adjacent to each cab side window. Microphones shall allow the Attendant (or Operator) to make Public Address (PA) announcements while leaning out of the window. Microphone cord shall be a minimum of 4 feet (1.2 m) long, fully extended.

F. A gooseneck microphone shall be incorporated in or near the console. A push-to-talk pushbutton shall be located on the cab console. The microphone shall provide sufficient adjustable flexibility to allow an Operator to access it by leaning forward from a seated position.

G. An Automatic Announcement Control Panel shall be located adjacent to the CCP.

H. See T 13, Communications & Passenger Information System, for detailed system requirements.

5.03.16. Parking Brake Control

A. The parking brake shall be applied whenever a direction is not selected from the Master Controller.

B. Provision for manual release and re-application of the parking brake shall be provided in the cab of each car, at a location easily accessible by the Operator. Non-Cab Car Releases shall be housed behind hinged access panels opened with an Authority crew key.

C. Parking brake details and performance requirements are contained in T 12, Friction Brakes & Pneumatic System.

5.03.17. Miscellaneous Cab Controls

A. The Train Shutdown switch on the cab console shall allow the Operator to 'hard boot' the train in an attempt to clear a fault that prevents the train from continuing in service.

1. The train shutdown switch shall be designed to avoid accidental activation.
2. The Train Shutdown switch functionality shall be disabled whenever the car is keyed up.
3. Once the car is keyed off, application of the Train Shutdown switch shall de-energize all systems and disconnect all connections to the battery with the exception of the emergency lights.
4. Keying the car back on will re-energize the systems.

B. An odometer shall be installed in the cab in an easily viewable location. Mileage display shall contain a minimum of 7 digits. Digits shall be a minimum of 1/4" (6.3 mm) tall.

C. The security alert momentary pushbutton in the cab shall illuminate the security indicator light on both exterior sidewalls of the vehicle. The pushbutton shall not be labeled and shall be located in a concealed position accessible to the seated Operator, such as on the underside of the console. The Location shall be finalized during mock up review.

5.04: CAB EQUIPMENT

5.04.01. Forward Facing Camera

A. A camera shall be mounted within the interior of the Operator's cab and be arranged to record the view directly in front of the car.

B. The lens shall be positioned and sized to clearly capture a person standing 100 feet (30.5 m) in front of the train on the track centerline as well as the rails and track bed 5 feet (1.5 m) in front of the train.

C. The camera shall be located so that it does not detract from the Operator's space envelope or visibility.

D. The camera shall be housed in an enclosure that provides protection. The enclosure shall be heated, if required, to prevent condensation from forming on the viewing surface.

5.04.02. Operator's Seat

A. The Operator's seat shall be of transportation grade as manufactured by Recaro, or approved equivalent.

B. Seat shall be fully adjustable in height, longitudinal position, horizontal rotation, seat back angle, arm rest vertical position, and lumbar support. Travel in each direction shall be sufficient to satisfy the ergonomic requirements of 5th percentile female and 95th percentile male as well as the visibility requirements detailed in T 05.02.06, Windshield.

C. Not used.

D. The seat shall be upholstered with transit grade material. A sample shall be provided during design review. Seat cushions and upholstery shall meet the smoke, flame and toxicity requirements of T 18, Materials & Workmanship.

E. Not used.

5.04.03. Instructor's Seat

A. A foldable instructor's seat shall be mounted on the left side of the cab. The seat shall be sturdy in construction but designed to stow away with a minimal use of clear floor area.

B. The seat shall be provided with padding and transportation grade material to provide a comfortable position for instructors.

C. The seat location shall provide a clear view of the Operator and ROW through the left side windshield.

D. The seat shall be designed to support a load of 400 pounds (181 kg) without permanent deformation.

5.04.04. Cab Interior Lighting

A. Cab interior lighting fixtures shall be directionally adjustable and located on both sides of the cab.

B. Cab interior lighting fixtures shall be powered from the emergency lighting circuit.

C. Cab interior lighting shall include auxiliary lights for breaker panels, equipment lockers and cutout enclosures.

D. All Cab lighting shall be dimmable.

E. Console lighting shall be sufficient to illuminate all controls without the need of the overhead lighting.

F. See T 08, Lighting, for performance requirements.

5.04.05. Convenience Outlet

A. A duplex 120 volt convenience outlet shall be provided in the cab. The outlet shall be a heavy duty, industrial style rated for 20 amps. The outlet shall include ground fault trip and reset buttons.

B. See 14.02.23, Convenience Outlets, for additional outlet requirements in the passenger area.

5.04.06. Miscellaneous Cab Interior Appointments

A. The contractor shall proved a Universal Service Port (USP) to allow maintenance personnel to comment a laptop and access any end station, or switch on the vehicle or in the consist, through an industrial D coded M12 connector conveniently located in the cab.

B. A heavy-duty, flush mounted coat hook shall be located in a suitable location within the cab.

C. A sun visor shall be provided at the Operator's window. The visor shall be fully adjustable over the range of the windshield and designed to rotate and cover the side window. The visor shall be fabricated from polycarbonate with a thickness no less than 1/4" (6.4 mm). If a translucent visor is proposed, the material shall not distort the color of objects viewed through the visor.

D. A footrest shall be provided under the Operator's console. Size and range of adjustment (if required) shall be determined through the Contractor's ergonomic studies.

E. A storage locker shall be provided for the Operator's personal effects. The storage locker shall be fitted with a lock that is opened with the Authority crew key. The locker shall provide a minimum of 0.25 cubic ft (7080 cubic cm) of storage space.

F. HVAC equipment (cab heater, overhead diffuser, etc.) shall be in accordance with T 07, Heating, Ventilation & Air Conditioning.

5.04.07. Special Tools

A. Insulated tools shall be provided to lift collector shoes off live third rail and secure (hang) the shoes in the lifted position. Two lifting tools and eight hangers shall be securely stowed in the cab yet readily accessible to the Operator. Refer to section T

09.03.01, Third Rail Shoes and Holder Assembly.

5.05: NON-CAB CARS

5.05.01. Equipment Layout

A. The Authority has elected to procure Married Pairs with a single cab per Married Pair, to maximize passenger occupancy. The Contractor shall design the Married Pair such that most control equipment is located in the Cab Car and the additional passenger area in the Non-Cab Car is maximized for additional seats and standee area.

B. All control equipment housed in the Non-Cab Car shall be easily accessible through hinged access covers that are opened with the Authority crew key.

C. A layout of the Non-Cab Car that depicts the passenger standee area, seats, space allocated for equipment enclosures and a list of control equipment housed in the enclosures shall be submitted to the Authority for review and approval. [CDRL 05-10]

5.05.02. Hostler Panel

A. The No. 1 end of Non-Cab Car (rear end of the Married Pair) shall be fitted with a hostler panel on the end wall. The hostler panel is only intended for use during vehicle hostling in yards and rescues, rather than revenue service. The panel shall be mounted horizontally, below the windshield such that an Operator may manipulate it and monitor car movement and coupler operation through the windshield on the right side of the car. The Hostler panel layout shall be arranged in a similar fashion as the cab console (i.e. master controller on right side).

B. All Non-Cab Car controls shall be protected behind access covers that are hinged and fitted with locks that open with an Authority crew key. Access covers shall include hold-open devices. Panels shall automatically lock when closed. LED lighting shall be provided to illuminate controls when access doors are opened. All equipment controls behind access covers shall include automatically enabled LED lighting.

C. The hostler panel shall include the transfer switch as used in the cab, as well as the Forward-Reverse-Store direction switch. The hostler panel master controller must be in the Full Service Brake position to remove the transfer switch key or change direction switch position.

D. Hostler panel controls shall include a compact master controller type slide bar to control traction motors and brakes. Sliding the handle forward shall progressively introduce tractive effort while sliding it backward shall introduce increasing braking effort. The handle shall be spring loaded to revert to the full service brake position when released.

   1. A coast command will be included in the midrange of travel. A detent shall provide a tactile indication that the handle is in the coast position.

E. Activating the hostler panel shall automatically request Hostler Mode from the ATP system. The ATP system shall enforce a 10 mph (16 km/hr) speed limit. If the ATP system is not functional, the emergency bypass switch in the cab car must be thrown. Maximum speed in emergency bypass shall be 25 MPH (40 km/hr).

F. The hostler panel shall have a switch to select normal or reserve ASR active. (Refer to T 15.02.08.

G. Emergency braking provisions shall be incorporated into the design.

H. Additional controls shall include headlights, horn, couple, uncouple trainline, uncouple mechanical, windshield heater, windshield wiper and bell, as well as any additional controls required for safe operation of the train from the hostler panel. These controls shall function in accordance with the cab specifications.

I. All controls shall be momentary, with the exception of the emergency stop switch, windshield heater and windshield wiper, which shall be identical to those used in the cab. Uncouple buttons shall be shielded in a similar manner as applied in the cab.

J. All controls and relays shall be disabled when the transfer switch key is removed.

K. Hostler panel layout and proposed hostler panel Master Controller shall be submitted for Authority review and approval. [CDRL-05-11]

L. The following LED indicators shall be provided on the hostler panel:

1. Brake Fault
2. Door Summary Loop
3. Door Interlock Bypass
4. No Motion Bypass
5. Parking Brake On
6. Normal ASR active
7. Reserve ASR active
8. Heated Windshield On

5.05.03. Additional Equipment Requirements

A. A vertical grab bar on the left side of the window for Operator use while manipulating the hostler panel controls. The grab bar shall be designed in accordance with T 14.02.02, Stanchions & Hand Rails.

B. Duplex air gauges as detailed in T 05.03.13 shall be provided behind the hinged hostler panel access door.

C. Non-Cab Car wiper/washer for the right-side windshield shall be designed in accordance with T 05.02.07.

D. Non-Cab Car windshield for the right-side shall be designed in accordance with T 05.02.06. Non-Cab Car windshield heater shall be disabled when the Transfer switch key is removed.

1. Left side windshield shall conform to the requirements of 05.02.06, but shall be unheated, FRA type 2.

E. The horn shall be in accordance with T 05.02.09.

F. Red marker lights, tail lights as well as headlights shall be provided and shall function as described in T 08, Lighting.

G. A Non-Cab air manifold and cutout cocks as described in T 05.03.14, shall be fitted behind equipment enclosures.

H. A Communications Control Panel as described in T 13 shall be included in the vicinity of the hostler panel, accessible to an operator while car moves are being made. Refer to T 05.03.15 for specification requirements.

I. All circuit breakers, bypass switches and additional controls required for control of equipment in the Non-Cab car (except high voltage breakers, located under the car) shall be located in an easily accessible locker and be designed in accordance with T 05.03, Cab Controls.

5.05.04. Not used

5.05.05. Interior layout

A. The interior flooring, sidewalls, ceiling panels, overhead lighting, air diffusers and corner hatches of the passenger area shall seamlessly extend to the No. 1 end wall of the Non-Cab Car. End wall lining and door pocket treatment shall be consistent with the No. 2 end.

B. Sliding cab side windows shall not be installed in the Non-Cab Car. The glazing shall be a single, fixed, FRA type 2 window designed for installation with a frame similar to that used on the cab sliding window.

5.06: PERFORMANCE

A. All Cab Car and Non-Cab Car components which will be exposed to water as a result of wind-driven rain entering through an open cab side window shall be tested to ensure that damage, oxidation or premature failure do not occur as a result of repeated exposure. All cab surfaces shall include a slight slope to ensure that water drains to the cab floor.

B. All other performance requirements are included with the component descriptions of this section (T 05) or within the referenced sections of the specification, where applicable.

5.07: QUALIFICATION TESTING

5.07.01. General

A. Although most performance testing within T 05 shall be conducted on the pilot car, in accordance with T 20, Testing & Validation, the items below require factory testing or testing on the mock up prior to vehicle installation. Testing shall be done in a housing that replicates the vehicle installation structure. Qualification Test Procedures [CDRL 05-12] prior to testing and reports [CDRL 05-13] after testing shall be submitted for Authority review and approval.

5.07.02. Cab Side Windows - Federal Railroad Administration (FRA) Testing

A. A production Cab side window shall be supported by a fixture that simulates the carshell window aperture. The window shall be installed with a production frame and tested for compliance with FRA type 2 requirements. (T 05.02.05)

5.07.03. Windshield - FRA Testing

A. A production windshield shall be supported by a fixture that simulates the carshell window aperture. The window shall be installed with a production frame and tested for compliance with FRA type 1 requirements. (T 05.02.06)

5.07.04. Fixed Cab Side Window

A. A production side window, used in the Non-Cab Car, shall be supported by a fixture that simulates the carshell window aperture. The window shall be installed with a production frame and tested for compliance with FRA type 2 requirements. (T 05.05.05)

5.08: RELIABILITY

Cab Equipment & Controls shall provide a Mean Distance Between Component Failure (MDBCF) above 300,000 miles (482,800 km).

5.09: MAINTAINABILITY

Maintainability requirements are stated in the component descriptions of this section (T 05) or within other referenced sections of the specification, where applicable.

5.10: SAFETY

5.10.01. Emergency Evacuation Ladders

A. An evacuation ladder with handrails shall be provided in the cab of each cab car. The ladder shall be non-conductive and of sufficient width and strength to support the evacuation chair described in T 05.10.02 and a 450 lb (205 kg) passenger load.

B. The ladder shall be equipped with pins that fit into holes on the anticlimber, so that the ladder is fixed in place when deployed. Alternate arrangements that provide a secure ladder attachment may be proposed for Authority acceptance.

C. Ladder shall be secured within the cab with a quick release mechanism.

D. The Non-Cab Car shall be fitted with a nonconductive collapsible ladder, proposed by Contractor for acceptance by the Authority.

5.10.02. Emergency Egress Chairs

A. A chair shall be provided in each cab to assist in the evacuation of mobility impaired passengers through the end doors of the car.

B. The chair shall be designed with runners that slide down the emergency evacuation ladder described above.

C. The chair shall be foldable, as manufactured by Stryker (model #6253) or Authority accepted equivalent.

D. The chair shall be of sufficient strength to support a 450 lb (205 kg) passenger.

E. The chair shall be secured within the cab in a position that does not impede on the Operator's access to cab equipment. The chair shall be secured in place with a quick release mechanism.

5.10.03. Evacuation Stretchers

A. A stretcher shall be provided in each cab to assist in the evacuation of injured passengers or crew members through the end doors of the car.

B. The stretcher shall be the type currently in use on the Authority's existing cars.

C. The stretcher shall be stored in the cab and secured in place with a quick release mechanism.

5.10.04. Emergency Brake Push Button

A. An electro-pneumatic emergency brake push button shall be prominently located on or near the driver's console. The pushbutton shall be fitted with a large, red mushroom head. Pressing the button shall mechanically vent the emergency brake pipe of the train-set.

B. See T 12, Friction Brakes and Pneumatic System, for functionality and performance requirements.

5.10.05. Fire Extinguishers

A. 10 and 20 lb (4.5 and 9 kg) ABC type fire extinguishers shall be provided in the No. 1 end of each Cab Car and Non-Cab Car. The locker in the Non-Cab Car shall be fitted with a frangible polycarbonate window of sufficient size to allow quick removal of either extinguisher. High Performance Photo Luminescent (HPPL) signage, locker location and extinguisher attachment technique shall be proposed by the Contractor during the mock up for review by the Authority.

B. The Authority's crew key may also be used to open a hinged cover and access the extinguishers.

5.11: COMPATIBILITY

A. The Red and Orange Lines shall be equipped with identical controls and interior/exterior appointments. Liners, cab wall and floor panels shall be car-specific due to the difference in width and height of the vehicles.

5.12: CDRL ITEMS REFERENCED

CDRL 05-01, “Operator Ergonomics Investigation”, (Ref: T 5.01.01.A)

CDRL 05-02, “Cab General Arrangement Drawing”, (Ref: T 5.02.04.C)

CDRL 05-03, “Operator Access to Sliding Cab Window”, (Ref: T 5.02.05.F)

CDRL 05-04, “Ergonomic Investigation of Operator field of View”, (Ref: T 5.02.06.B)

CDRL 05-05, “Protection from Reflections on Windshield”, (Ref: T 5.02.06.D)

CDRL 05-06, “Dead Man Feature on Master Controller”, (Ref: T 5.03.02.A.9)

CDRL 05-07, “Inching Switch Enabling Concept”, (Ref: T 5.03.02.E.3)

CDRL 05-08, “Audible Enunciators”, (Ref: T 5.03.09.B)

CDRL 05-09, “Cab Air Manifold”, (Ref: T 5.03.14.D)

CDRL 05-10, “Non-Cab Car Layout drawings”, (Ref: T 5.05.01.C)

CDRL 05-11, “Hostler Panel Layout drawings and Hostler MC”, (Ref: T 5.05.02.K)

CDRL 05-12, “Qualification Test Procedures”, (Ref: T 5.07.01.A)

CDRL 05-13, “Qualification Test Reports”, (Ref: T 5.07.01.A)

CDRL 05-14, “Sample sliding window”, (Ref: T 5.02.05.D)

5.13: REFERENCES

5.13.01. Standards Referenced

49 CFR Parts 37 and 38, Americans with Disabilities Act

49 CFR Parts 239, Passenger Equipment Safety Standards, Final Rule

APTA draft, Standard for Rail Transit Vehicle Emergency Exits

ASTM E162, Flame Spread Index

ASTM E662, Optical Smoke Density

BSS-7239, Boeing Toxicity Standard

NFPA 130, Standard for Fixed Guideway Transit and Passenger Rail Systems

Mil-Std 1472F, Human Engineering Design Criteria for Military Systems, Equipment and Facilities.

SAE J1050, Describing and Measuring the Driver's Field of View

SAE J287. Driver Hand Control Reach

5.13.02. Technical Specification Cross References

T 01, General
T 02, Vehicle Design Requirements
T 03, Carbody
T 06, Passenger Doors & Controls
T 07, HVAC
T 08, Lighting
T 09, Power Distribution & Auxiliary Electrical Equipment
T 12, Friction Brakes & Pneumatic Systems
T 13, Communications & Passenger Information Systems
T 14, Interior & Exterior Appointments
T 15, ATP &ASR
T 16, Vehicle Monitoring System
T 18, Materials & Workmanship
T 20, Testing & Validation
T 24, Trainlines & Networks

PART T 06.00
PASSENGER DOORS & CONTROLS

Table of Contents

6.01: GENERAL

A. The passenger side door system shall be a bi-parting, sliding pocket type, configured to provide free flow access for all passengers.

B. Door operators shall allow the operation of one leaf when the adjacent leaf is disabled or locked out. One operator per leaf is envisioned to satisfy this requirement.

C. The door operator shall either be a spindle arrangement or a linear induction motor. The system shall be located under the hinged covers located directly above the door leaves.

D. The passenger side door system shall be fully compliant with all applicable Americans with Disabilities Act (ADA) requirements (Per 49 CFR 38).

E. Platform to vehicle floor gap mitigation devices shall be provided in Cab Cars at the two doorways nearest the cab. Devices shall be deployed/retracted by the Operator with a pushbutton. (OPTION)

6.02: SYSTEM DESCRIPTION & CONFIGURATION

A. The passenger side door system shall use electric door operators driven by microprocessor based controllers. The door system operation shall be controllable from the Operator's cab, trainline signals, key operated crew switches and passenger pushbuttons. The door system shall comply with the recommendations of APTA SS-M-18-10, as applicable for a bi-parting passenger door system.

B. The gap mitigation device system shall work in conjunction with the door system to provide a safe, reliable system. (OPTION)

6.02.02. Passenger Door System Configuration

A. The Red Line vehicles shall have 8 doorways per car and the Orange Line vehicles shall include 6 doorways per car. Doorways shall be located laterally opposite each other. The door open clear width shall be 64 inches (1626 mm) minimum with two door leaves open and 32 inches (813 mm) with a single leaf open.

B. The doors shall be driven by high reliability overhead electric operators. The door panels shall be supported at the top using ball or roller bearing mechanisms and guided at the bottom in a track at the door threshold. The door system operation shall allow the cut-out of a single door panel, while allowing full operation of the remaining panel.

C. The lower door guide track shall extend the full range of the door panel movement. The guide shall be designed to preclude the accumulation of liquids and debris.

D. The door operator, control panel, and upper door track shall be accessible for maintenance through a hinged cover. The cover shall be easily accessed using only the Authority crew key, and shall swing upward when unlocked to allow unimpeded access to all door operator and control equipment. A hold-open device shall be used to support the cover in an open position during maintenance or servicing. The hold-open device shall be easily and securely stowed when not in use.

E. The door motor cover shall also be fitted with LCD screens (OPTION) and LED route maps (OPTION) for passenger information systems. See T 13, Communications & Passenger Information Systems, for more information.

F. The door controllers shall be PTU accessible through an industrial D coded M12 connector.

G. The door controller shall have a network interface as described in T 24, Trainlines & Networks, for the purpose of communicating real-time faults to the Vehicle Monitoring System. Refer to T 16, Vehicle Monitoring System.

H. The perimeter of the door pocket shall be equipped with a brush or similar device to prevent the possibility of passenger injury during the opening or closing of the door panels.

I. The bottom of each door pocket shall include easily accessible provisions for drainage of any collected water. Drain tubes shall be fabricated from stainless steel and terminate below the bottom of the side sill, clear of any undercar equipment.

6.02.03. Door Numbering

A. Door numbering shall be in accordance with the figure below.

B. The No. 1 leaf is nearest the No. 1 end. The No. 2 leaf is nearest the No. 2 end.

C. Doors shall be labeled as described in T 14, Interior & Exterior Appointments.

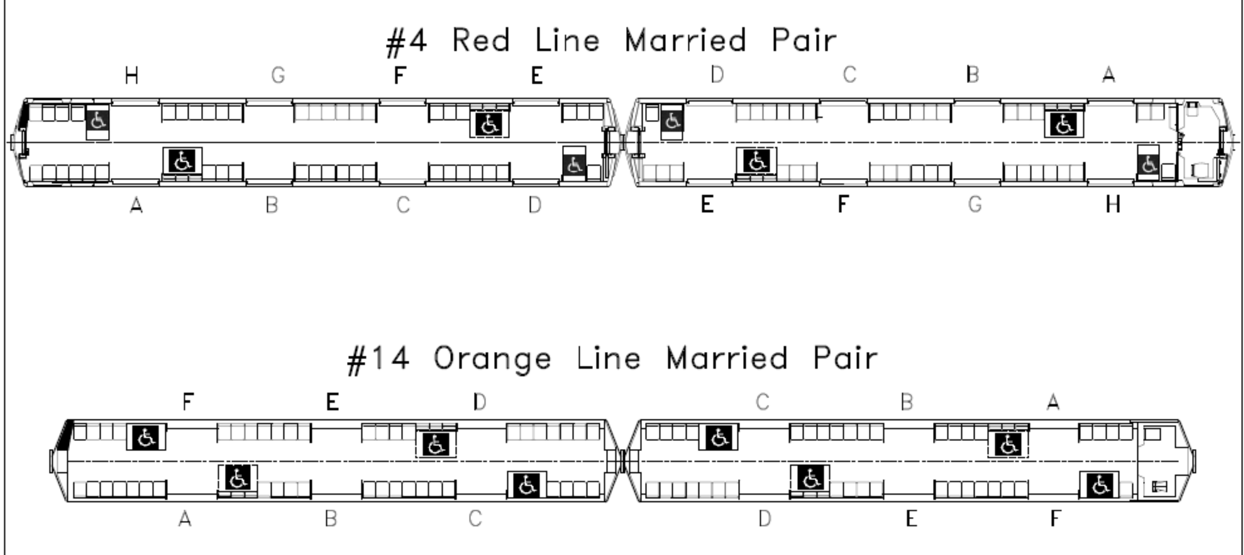


Figure 06-1 Door Numbering

6.02.04. Door Operators

A. The door operator shall be an electrically driven design operated by a microprocessor based door control module. The number of couplings and linkages in the door operator shall be minimized to reduce the number of failure points in the system. The operator design shall be service proven, previously used in an equivalent door arrangement design.

B. The door operator, hanger and door controller shall be of modular design, packaged to allow quick removal and replacement. Individual door operating system components shall not be mounted to the car structure.

C. The door control system shall include features to automatically adjust to normal wear, frictional changes and environmental conditions listed in T 02, Vehicle Design Requirements. Alternative approaches may be proposed for Authority consideration.

D. The door operator shall be equipped with position sensing devices for the controller to monitor the door position.

   1. Proximity type switches may be used for position sensing to indicate door open and door closed. Service proven limit switches may be proposed for Authority consideration.

E. The door system shall be entirely powered from the DC Low Voltage Distribution Network system. Door controllers shall be energized whenever low voltage power is present.

F. The design shall be failsafe such that any failure condition with the door control shall signal the doors to automatically close and lock. Upon restoration of operator control the doors shall remain in the closed and locked position until release or open signals are sent by the operator, either with the cab controls or locally at the door.

G. The door operator shall incorporate devices for auditory and visual warning signals to alert passengers of open and closing doors. Signal timing shall be adjustable by the Authority without the need to modify the software version.

H. Circuit breakers for overload protection shall be provided at each door operator and at the circuit breaker panel for the door operator system. Circuit breaker rating and wiring sizing shall consider that some stations may open/close all doors on both sides of the train at the same time. Refer to T 09, Power Distribution & Auxiliary Electrical Equipment, and T 18, Materials & Workmanship.

I. If a failure of one door leaf occurs, a cut out switch/mechanical lock shall be provided to remove power, disable operation, securely lock the leaf in the closed position and prevent it from opening. Normal operation of the adjacent leaf shall not be affected by the failure.

J. Electric operator design, layout and functional narrative, including a description of independent door panel control with one panel locked out, shall be submitted for Authority review and approval. [CDRL 06-01]

6.02.05. Door Locking

A. The door lock shall be independent from the door operator and linkage. The locking mechanism shall be a spring loaded latch system, or similar device, that positively retains the door panel after the panel reaches its closed position.

B. There shall be no door operator failure mode that could cause an unintentional unlocking of the door panel.

C. Door unlocking shall be accomplished by an independent mechanical device, such as a solenoid or similar component that energizes only after trainline signals have been received indicating "doors unlock", "doors open" and the local car No-Motion signal is detected.

   1. Alternative door locking techniques which have been proven to provide a fail-safe, positive locking may be proposed for Authority consideration.

D. The lock position shall not be used to indicate the position of the panel.

E. Door locking system, door locked detection technique, functional narrative and detailed layout shall be submitted for review and approval by the Authority. [CDRL 06-02]

6.02.06. Door Control Logic

A. The door controller shall be microprocessor based. All non safety-critical processes shall be performed by the microprocessor. Discrete trainline interfaces (both inputs to the trainlines and outputs from the trainlines) shall utilize relay logic and not rely strictly on outputs from the microprocessor. The Contractor shall propose a fail-safe scheme for review and approval by the Authority. [CDRL 06-03]

B. The non-volatile fault memory shall be designed in accordance with T 16, Vehicle Monitoring System.

C. The controller(s) shall coordinate the timing of door leaves to ensure that both reach the fully closed and the fully open positions at the same time (±250 ms).

D. The door control unit shall provide information sufficient for maintenance personnel to perform basic diagnostic functions and troubleshooting. LED indicators, or equivalent, may be used for this purpose.

E. The diagnostic features visible at the local door or Operator's display (without requiring attachment of the PTU) shall include the following:

   1. Actual door state - open, closed, enabled, cut-out, etc.

   2. Command status for open, close, enable functions

   3. Door lock status - locked, unlocked, emergency release activated (both internal and external)

4. Bridging device status – locked, unlocked (OPTION)
5. Cut-out switch status - normal operation or cut-out
6. No-Motion interlock status
7. Crew switch status (local door)
8. Obstruction detection status
9. Fault status (door and bridging device, if equipped)
10. Door system power status - nominal voltage, low voltage

F. The visual system status indications shall be labeled with sufficient detail to identify the system state or function of each indication.

G. The door controller layout, software features, configuration and graphical interface shall be submitted for authority review and approval. [CDRL 06-04]

6.02.07. Diagnostics and Fault Reporting

A. The door system shall include a diagnostic system that shall continuously monitor operation of door and door control systems. Any failure or fault condition shall be automatically stored (along with a time-date stamp for the incident) in the non-volatile memory of the door control unit for each leaf or doorway and be reported to the Vehicle Monitoring System (VMS) in accordance with T 16, Vehicle Monitoring System.

B. The controller shall include self-diagnostic functions that shall be initiated with the use of the Portable Test Unit (PTU), either in the cab or locally on the door control unit.

C. The door controller diagnostic system shall be capable of detecting failed components down to the Lowest Line Replaceable Unit of the door system. The diagnostic system scheme and features shall be submitted for authority review and approval. [CDRL 06-05]

D. The following data recorded at the time of fault shall be accessible via the PTU:

1. The time and date of the fault or failure condition
2. The door system command state during the fault
3. The obstruction detection status
4. The bridgeplate status and position (OPTION)
5. No-Motion status during the fault
6. Door system power status - nominal voltage, low voltage

7. The door panel and door operator position during the fault

8. Total number of door and bridgeplate cycles per day and per year as well as total number of cycles to date

E. The Fault data shall indicate the fault type and details without the use of cross references.

F. Upon detection of a door system fault or failure condition, the door open indicators adjacent to the doorway shall flash until the fault is cleared or the door is closed and locked out.

G. Refer to T 16, Vehicle Monitoring System, for additional information.

6.02.08. Door Panels

A. The passenger side door panels shall be made of stainless steel with a nominal overall thickness of 1-1/4 inch to 1-1/2 inch (31.8 mm to 38.1 mm). The panel construction shall be honeycomb core faced with stainless steel sheets finished with an approved, horizontal grain brush finish to match the carshell. Stainless steel reinforcements shall be provided internally, as necessary, for the attachment of all door hardware. The stainless steel alloy selected for the door facing shall not show signs of rust or discoloration in normal use on the Authority's system. All seams and edges of the door panel shall be thoroughly sealed against moisture. Condensation drain holes shall be provided in the bottom of the door panels. The panels shall be treated with the anti-graffiti coating approved for use on the carshell.

B. The interior surface of the door panel shall be finished to complement the interior color scheme, as selected from Contractor renderings described in T 01, General.

C. The door panel shall contain a fixed window mounted in an endless neoprene glazing strip. Other types of rubber may be proposed for Authority review and acceptance. The glazing and mounting shall meet the requirements of ANSI Z26.1, "American National Standard for Safety Glazing Materials for Glazing Motor Vehicles and Motor Vehicle Equipment Operating on Land Highways – Safety Code. The glazing strip shall use zip-strip type retention for easy re-glazing from the car exterior, without the need for sealing compounds. The zip-strip shall be an inherent part of the glazing strip. The glazing strip shall not project beyond the surface of the interior or exterior door panel skin. The window retention profile shall be rounded to facilitate cleaning and preclude build-up of dirt and debris. The window height shall be identical to that of the side windows and located to align with them when the door is installed and adjusted. Window width shall be as wide as feasible, but in no case less than 22 inches (559 mm).

D. The door panel leading edges shall be equipped with an elastomeric nosing seal designed with an overlapping profile. The hardness of the seal shall be suitable to achieve proper sealing against water and air under all modes of operation and environmental conditions specified in T 2, Vehicle Design Requirements. The nosing seal shall allow proper operation of the obstruction detection system, and also allow withdrawal of small objects that are not detected. The nosing shall slide into a channel on the front face of the door panel to provide robust installation yet easy removal and replacement. The nosing shall be replaceable without requiring door removal. Elastomeric seals shall be provided at the rear edge of the door panel to seal when the door is closed. All seals shall accommodate the adjustment range of the door panel.

E. The door panel bottom guides shall be easily replaceable. The guides shall be faced with a low friction polymeric material for long wear and quiet operation. The guides shall extend the full width of the door panels but not exceed the door width. (There shall be no interference between door guides.)

F. All locations where fastening hardware installs to the door panel shall be reinforced and fitted with threaded inserts or tapping plates.

G. The door panel shall be insulated as necessary to meet the thermal and noise attenuation requirements of T 02, Vehicle Design Requirements.

H. Not used.

I. The door panel design shall be submitted for Authority review and approval. [CDRL 06-06]

6.02.09. Upper Door Track and Bottom Guide

A. The upper Door Track/Hanger shall be bolted to the car secondary structure through threaded inserts or tapping plates.

B. The door panel upper track shall be equipped with sealed roller bearings designed to require no maintenance or lubrication for the life of the system. Alternate approaches may be proposed for Authority review and acceptance.

C. The track shall allow panel adjustment in both horizontal and vertical directions with an eccentric nut, or similar arrangement reviewed and accepted by the authority.

D. Panel removal and replacement shall not require removal of the track, hanger, or any operator components.

E. Door travel shall be limited by the door operators. In case of a fault in the operator or encoder, adjustable bump stops on the track or door pocket shall ensure that opening or closing of the doors does not cause the panel to become misaligned or damaged.

F. The door panel bottom guide shall slide along a track that is open to the Right of Way (ROW) under the door. Sand, salt and dirt shall fall directly to the ROW rather than collect in the door track. Refer to T 14.03.03, Thresholds, for additional information.

6.02.10. Gap Mitigation Devices / Bridging Mechanism (OPTION)

A. A platform to floor threshold bridging device shall be provided at the left and right doorways nearest the cab in Cab Cars only. The bridging device shall be capable of bridging the horizontal gap between the doorway threshold and the edge of the platform. The gap variation range is provided below:

Orange Line	**Variation**		**Range**
Vertical Gap	+3¾" (95.2 mm)	-2" (50.8 mm)	5 3/4" (146 mm)
Horizontal Gap	7" (Maximum) (177.8 mm)	1" (Minimum) (25.4 mm)	6” (152.4 mm)

Red Line	**Variation**		**Range**
Vertical Gap	+4½" (114.3 mm)	-3" (76.2 mm)	7½” (190.5 mm)
Horizontal Gap	6" (Maximum) (152.4 mm)	1" (Minimum) (25.4 mm)	5” (127.0 mm)

B. The bridging mechanism shall be deployed by a Bridgeplate Deploy Pushbutton in the cab. It shall deploy only when the train is stopped. The bridging mechanism shall fully retract and stow when the Bridgeplate Retract Pushbutton is depressed.

1. The bridging mechanism shall not deploy if either door leaf is locked out of service.

2. The bridging mechanism shall be deployable on the side of the car that the doors are open. If both sides are open, both mechanisms may be deployed.

3. Upon activation the associated door leafs shall close before the bridging device deploys. When fully deployed the doors shall open.

4. Upon de-activation the doors shall close and the device retract.

C. Bridgeplate Request pushbuttons shall be fitted at ADA compliant locations on the interior and exterior of each of the doorways fitted with bridging mechanisms.

1. Pushbutton illumination shall follow the scheme described in T 06.03.03, Internal and External Passenger Door Open Buttons.

2. Pushbutton activation shall sound a tone in the cab and illuminate an indicator on the dash until the Bridgeplate Retract pushbutton is energized.

3. Pushbuttons shall be designed in accordance with ADA guidelines.

D. Manual deployment and retraction shall be easily accomplished without the use of special tools.

E. It shall be possible to quickly and easily remove a fully deployed bridging device if the bridging mechanism is mechanically jammed.

F. The bridging mechanism shall be interlocked along with the door system in a failsafe manner to preclude any unsafe operation of the bridging mechanism system, or operation of the vehicle with a bridging mechanism not fully retracted.

G. Bridging mechanism shall employ a lock/cutout switch, closed indication device and locked indication device as described for the door system.

H. The Bridgeplate and bridging mechanism shall be fabricated from corrosion proof materials.

I. The bridgeplate/bridging mechanism design shall be submitted for Authority review and approval. [CDRL 06-07]

6.03: DOOR CONTROLS

6.03.01. Operator's Door Controls

A. Door control switch panels shall be provided in the Operator's cab, adjacent to the left and right side cab windows. The left side panel shall control doors on the left side of the train-set. The panel on the right side shall be fitted with controls for the right side of the train-set. Controls shall be arranged to allow the Operator or Attendant to lean out of the window while simultaneously opening or closing the doors.

B. Door control buttons shall be weather-proof and designed to prevent unintended activation. Buttons shall be arranged and designed to allow the Operator/Attendant to differentiate between them while viewing passenger egress and ingress. Refer to T 05, Operator's Cab, for additional information.

C. The door panel shall include permanent labels for each control. Metal etched engraving or similar method shall be utilized. Adhesive labels or silk screening shall not be accepted. The panel shall be finished with a permanent contrasting surface treatment.

D. The door control panels shall feature LED lighted Door Open, Door Close, Door Enable functions and a buzzer for Attendant communication with the Operator.

E. The Door Enable function transfers door control to the local door and illuminates “Door Open” LED pushbuttons inside and outside of each doorway, allowing passengers to open individual doors by pressing the “Door Open” button. LEDs shall be illuminated only when the Enable trainline signal is energized.

F. Each side of the cab shall contain the following pushbuttons for door and bridgeplate control (controlling only the doors/bridgeplate on that side of the car):

1. Door Open Forward
2. Door Open Rear
3. Door Close Forward
4. Door Close Rear
5. Door Enabled
6. Bridgeplate Deploy (OPTION)

7. Bridgeplate Retract (OPTION)

8. Door Buzzer (Refer to T 05, Operator's Cab.)

G. Sample door control pushbuttons shall be provided by the Contractor for review and selection by the Authority. [CDRL 06-08]

H. The door control panels shall be configured and incorporated into the cab design as defined in T 05, Operators Cab.

I. In addition to the door control panels, a Door Setup Switch shall be provided to allow each cab in the train-set to be set up as controlling ("ON"), receiving, ("THRU"), or end of train-set ("OFF"). Door Setup Switch shall be located remotely from other door controls and in an inconspicuous location, such as behind a hinged panel or within a compartment. Location shall be determined in cab mock up or design reviews. Refer to T 05, Operator's Cab, for additional requirements.

6.03.02. Trainlines, Cab Relays and Bypass/Cutout Switches

A. Each car shall include a Door Summary Relay. The Door Summary Relay shall be series wired through each door panel's door closed and door locked circuits as well as all bridging mechanism's closed and locked circuits. The Door summary Relay shall only energize if all circuits are closed and the Enable function is disabled (by a Close command). The Door Summary Relay shall be wired into the Doors Closed Summary Trainline in accordance with T 24 Trainlines & Networks.

1. Manually locking and cutting out a panel or bridgeplate shall bypass the closed and locked sensing devices.

2. Once the summary relays in all cars in a train-set are picked up, the Door Closed Indicator Light on the Operator's console shall energize in the lead car and propulsion/brake release shall be available.

B. A sealed Door Interlock Bypass Switch shall be provided that bypasses all door summary relays and allows propulsion to energize and brakes to release. The Door Interlock Bypass Switch shall be functional only from the controlling cab.

C. Two sealed Door Isolation Switches (one for Cab Car doors and a second for Non-Cab Car doors) shall be provided in the cab Cutout/Bypass Panel. When Cutout is selected, the car's door summary relay is made by the Isolation switch and the doors on the car are isolated from door open commands. (Refer to T 05 Operator's Cab and T 24 Trainlines & Networks).

D. Each car shall include a No-Motion Relay that shall energize when the car speed approaches zero.

1. The No-Motion Relay shall be interlocked with all door controls such that doors cannot be opened until the relay picks up.

2. A failure of the No-Motion Relay in the car that is configured to operate the train-set doors shall not affect the door controls of any other car.

E. All deployed bridgeplates (OPTION) and open doors on the car shall immediately be powered closed if the car's No-Motion Relay drops out.

1. The door control shall not allow the doors to be opened, enabled or activated until the train speed is below the No-Motion point. Door open and enable requests above the No-Motion point shall be cancelled. The door open or enable request must be received below the No-Motion point to be acknowledged.

2. A sealed No-Motion Bypass switch shall be provided in each car that overrides the car’s No-Motion interlock and allows the doors to be opened and bridgeplates to be deployed. (Refer to T 10, Propulsion & Dynamic Braking and T 05, Operator’s Cab).

F. The Door Control System on each car shall respond to the door control trainlines:

1. Doors Unlock Left

2. Doors Open Left

3. Doors Unlock Right

4. Doors Open Right

5. Doors Close Left

6. Doors Close Right

7. Doors Enable Left

8. Doors Enable Right

G. The Door Open Relays shall require the No-Motion relay to be energized and both the Door Unlock and the Door Open trainlines to be active for a particular side before microprocessors are allowed to open the doors.

H. The Door Close Left and Door Close Right trainlines shall be interlocked with the door open relay. Trainlined Close commands shall cause the door open relay to drop out, which will command all microprocessors to close and lock the doors.

I. All door control relays shall be located on a separate, dedicated relay panel.

J. Electrical schematics that convey compliance to these requirements shall be submitted for Authority review and approval. [CDRL 06-09]

K. See T 24, Trainlines & Networks, for additional information.

6.03.03. Internal and External Passenger Door Open Buttons (OPTION)

A. A passenger operated "Door Open" push button shall be provided adjacent to each doorway, on both sides, and on both the interior and exterior (4 buttons per doorway). The pushbutton shall be LED Lighted with amber LEDs indicating "Enabled" state.

When illuminated, the words “Push to Open” or a pictogram showing doors opening shall be clearly visible.

1. When the door system is in the "Enabled" state, the passenger doorway pushbuttons shall control the door "open" command for the local doorway. Both leaves of the local doorway shall open upon the momentary activation of the pushbutton. The doorway shall open and remain open for a predetermined time, adjustable from 10 seconds to 1 minutes, or until a closed command signal is sent by the Operator or Attendant. The time delay shall be easily adjustable with the PTU. Door indicators shall operate as described in T 06.04. Door closing shall be preceded by audio and visual warnings.

   a. The automatic close time-out shall include a setting that keeps doors open until a Close signal is received from Operator or Attendant.

2. The pushbutton shall remain in the “Enabled” state as long as the door is enabled for passenger operation. Door Enable is disabled when a Door Close command is sent.

3. The door pushbutton shall be interlocked in a failsafe manner to preclude any unsafe operation of the door system or operation of the vehicle with a doorway enabled.

4. Door pushbuttons shall be weather-proof.

B. Door pushbutton type, mounting location and configuration shall be submitted for Authority review and approval. [CDRL 06-10]

C. Similar pushbuttons and functionality shall be provided for the bridging device. Detailed descriptions of type, location, and configuration shall be submitted for Authority review and approval. [CDRL 06-19] (OPTION)

6.03.04. Crew Switches

A. Two interior and two exterior crew switches per car shall be provided for crew egress and ingress.

B. Crew switches shall be located adjacent to doors located nearest the No. 1 end of the Cab Car and the Non-Cab Car.

C. The crew switch shall be wired in a double-break manner and shall be operated by the Authority crew key. The switch shall operate the local doorway (both leafs) adjacent to the switch. The switch shall have 3 operating positions; Open, Neutral, and Close. A stainless steel faceplate shall be provided with the switch positions engraved and filled with contrasting paint. The switch shall be spring loaded to return to the central, Neutral position. Exterior crew switches shall be fitted with a sealed, stainless steel, spring-loaded cover to protect the switch from the elements.

D. The location and configuration of the crew switch, along with a sample (including cover), shall be submitted for approval by the authority. [CDRL 06-11]

E. The door operator and the adjacent crew switch shall be powered directly from the battery low voltage circuit and shall function when the vehicle is unpowered. Door operation from the crew switch shall be interlocked with the No-Motion circuit to preclude opening the door with the car in motion.

F. When Open is selected, the crew switch shall initiate a standard door open cycle.

G. Door Close shall initiate a standard close cycle.

H. A door opened with a crew switch may be closed with a crew switch at the local door or by the door close button of a cab with its Door-Setup-Switch in the ON position.

I. Refer to T 14, Interior & Exterior Appointments, for additional information.

6.04: DOOR INDICATORS

6.04.01. Door Status Indicators

A. Door Status lights shall be provided on the interior and exterior to monitor the door closed and locked status. The location and configuration of the indicator lights shall be submitted for Authority review and approval. [CDRL 06-12]

B. Indicator lights shall be provided as follows:

1. A red, tubular LED type Door Summary Indicator Light shall be provided on each side of the car. The light shall be energized when the door summary circuit is open (due to an open or unlocked door or bridgeplate). The light shall be clearly visible from the Operator's cab of the lead car.

2. A red, tubular LED type No-Motion By-Pass Indicator Light shall be provided on each side of the car. The light shall be energized when the No-Motion By-Pass switch is activated.

3. A red, LED type Door Leaf Open Indicator Light shall be provided adjacent to each leaf, on both the interior and exterior of the car. The light shall be illuminated when the adjacent door leaf is unlocked or open. Both lights within a doorway shall be illuminated if the bridgeplate is not closed and locked. Any door or bridgeplate that remains open or unlocked after a door closed request will be indicated on the VMS of all active cabs.

4. A Door Closed indicator shall be provided on each cab console and hostler panel. A green LED indicator shall illuminate only in the active cab (or activated hostler panel) when all doors in the train are fully closed and locked.

5. Door Interlock By-Pass indicator shall be provided on the cab indicator panel. The indicator shall be illuminated in the lead cab (or activated hostler panel) when the Door Interlock Bypass Switch in the cab has been placed in the bypass mode.

6. No-Motion By-Pass indicator shall be provided on the cab indicator panel and hostler panel. The indicator shall be illuminated when a No-Motion bypass switch in that Married Pair has been placed in the bypass mode.

7. A Bridging Device Closed indicator shall be provided on each cab console and hostler panel. A green LED indicator shall illuminate only in the active cab (or activated hostler panel) when the bridging device is retracted closed and locked. (OPTION)

C. Refer to T 08, Lighting, for additional information on indicator lighting.

6.04.02. Audible and Visual Door Closing Indicators

A. Audible chimes and visual indicator lights shall be provided at each doorway to annunciate an open door as well as the closing of the door. The devices shall be configured and located such that they may be heard and seen from both inside and outside the vehicle.

B. The purpose of the Door Open chime is to provide way finding for visually impaired passengers. An audible chime shall be located on or near each door operator and be activated only when both leaves are operable. The frequency of the Door Open chime shall be lower than the Door Closing warning chime. The Door Open and Door closing chimes may be integrated into the same device. The device shall be independent of the vehicle PA system.

C. Upon receiving the door closed command, the door controller shall initiate the door closing annunciation with a programmable time delay. The time delay feature shall be initially set to two seconds before doors begin to close, but shall be adjustable from one to ten seconds. The audible chime shall sound from the initiation of the door close command until the doors close. The Door Open chime may be used with an increased frequency to indicate closing doors. The Door Open indicator light shall commence flashing from the initiation of the door close command until the doors are closed and locked. The flash frequency shall be coordinated with the chime frequency to provide a pleasing, coherent indication.

D. The audible levels, frequency and duration of the Door Open and Door Closing chimes shall be independently adjustable. Adjustability shall include a setting to disable the functions.

E. The Contractor shall propose an arrangement (chime tone, frequency, etc) for this requirement for review and approval by the Authority. [CDRL 06-13]

6.05: MANUAL DOOR RELEASE

6.05.01. Manual Door Release

A. Interior and exterior Manual Door Releases shall be provided for all door leaves.

1. The manual door release shall be designed to be operable by Authority personnel or emergency responders without the use of any devices or tools.

2. The manual door release is not intended for use by passengers.

3. The release shall be actuated by a stainless steel bowden cable. Alternate methods for actuating the release may be proposed for Authority review and acceptance.

4. Activation of the manual release shall unlock and partially open the local door panel and enable the door panel to be manually opened, regardless of vehicle speed or door commands.

   a. The force required to activate the interior manual release shall not exceed 20 lbf (89 N).

   b. The force required to pull the exterior T-handle manual release shall not exceed 50 lbf (222 N).

   c. The force required to slide the door panel into the door pocket shall not exceed 45 lbf (200 N).

5. Activation of the manual release shall interrupt the door summary circuit, disable propulsion and apply full service brakes. Additionally, the VMS shall display the unlocked door and the door open indicator light shall be energized.

6. Re-setting the release mechanism and manually closing the doors shall automatically reset the emergency release cable.

B. The External Manual Release shall be provided in a flush mounted housing located adjacent to each door leaf.

1. The release shall be a T-handle or equivalent, recessed in a weather tight housing covered by a diagonal cross cut, flexible elastomeric cover.

2. The release shall be mounted as close the door opening as possible and approximately 12 inches (305 mm) above the top of floor.

3. Refer to T 14, Interior & Exterior Appointments, for additional information.

C. Not used.

D. The interior and exterior Manual Door Release configuration, handle locations and operation details shall be submitted for Authority review and approval. [CDRL 06-14]

6.06: PERFORMANCE

6.06.01. Door Movement

A. The door operation shall be smooth, quiet and free of vibration, shock and impacts. The controller and operator shall slow the motion of the door panels at the end of the stroke in both the opening and closing directions.

B. Door opening and closing times shall be independently adjustable via PTU, and initially set to provide door movement times of 2.5 seconds ± 10% to open, and 3.0

seconds ± 10% to close. The opening and closing time range of adjustability shall be between 2.0 and 3.5 seconds for opening, and 2.5 and 3.5 seconds for closing.

6.06.02. Water-Tightness

A. The doors shall be weather-stripped to prevent water from entering the vehicle during car washes, as well as all combinations of speeds and environmental conditions listed in T 02, Vehicle Design Requirements. See T 20, Testing & Validation, for detailed requirements.

6.06.03. Door Closing Force

A. The force of an impact on a person or obstacle shall be limited to a maximum of 65 lbf.

B. The effective mean force including further closing attempts after obstruction detection shall be limited to a maximum of 45 lbf.

C. These values shall be measured in accordance with the method described in EN 14752 Appendix D.

D. A force of 60 lbf (266 N) applied perpendicular to the door panel, at a vertical level of half the doorway height, shall not prevent the door from opening or closing.

6.06.04. Bridging Mechanism (OPTION)

A. The bridging mechanism shall be located under the finished floor and shall be designed to deploy and retract only when doors are closed. When requested while the doors are open, the doors shall close fully before the bridging device deploys or retracts.

B. The bridging device shall have sensors that immediately stop movement when an obstruction is sensed at its leading edge or on its top surface.

C. The bridging mechanism operation shall be smooth, quiet and free of vibration, shock and impacts.

D. The bridging mechanism deployment and stowing times shall be less than 2 seconds each.

E. The bridging device shall be capable of supporting persons in motorized wheelchairs.

6.06.05. Obstruction Detection

A. An obstruction detection system based on motor current draw, or similar approach, shall be provided for each door leaf. The system shall meet the following requirements:

1. It shall detect a flat bar, 1/4 inch (6.35 mm) wide and 3 inches (76.2 mm) high, held between and perpendicular to the door. This sensitivity shall be required

along the length of the panel except the uppermost 3 inches (76.2 mm) and lowermost 1 inch (25.4 mm) of the door leading edges.

2. It shall detect an object, 3/8 inch (9.5 mm) in diameter, held between and perpendicular to the door panels at all locations along the length of the door leading edges, except the uppermost 3 (76.2 mm) inches and lowermost 1 inch (25.4 mm) of the seal.

3. The equipment shall permit a thin flexible object not detected by the detection system to be pulled free from the leading edges of doors that are fully closed and locked.

B. The obstruction detection system shall stop the door panel from closing when impeded, causing it to fully reopen. The door panel shall then pause for an adjustable time period, initially set at 1/2 a second, and then commence closing. The door panel shall continue to recycle in this manner until the obstruction is cleared and the panel successfully closes, or until a pre-set number of recycles has been reached. The recycles shall be adjustable between 1 and 10 cycles, and initially set to 3 recycles. If only one door panel is obstructed in a doorway, the unobstructed panel shall close and lock.

6.07: COMPONENT QUALIFICATION TESTING

6.07.01. General

A. Prior to installation on the pilot car, the first set of doors and bridgeplates shall be qualification tested. Test procedures shall be submitted for Authority review and Approval. [CDRL 06-15]

B. Test Reports shall be submitted for Authority review and approval. Unit First Article Inspection (FAI) acceptance shall be subject to successful completion of the Qualification Tests. [CDRL 06-16]

6.07.02. Life Cycle Tests – Door Operators

A. The door system shall be given a 1,500,000 cycle test. The test shall utilize production parts, including door panels, sealing rubbers, brushes, etc. Door pockets and car structure shall be mocked up to simulate the vehicle installation.

B. Testing shall run 24 hours per day, 7 days per week until completion of the test. Doors opening and closing speeds shall be set to the fastest setting. The test shall consider a full door cycle, including door closed and locked acknowledgement.

C. Obstruction Detection in accordance with the minimum detectable requirements of this specification shall be introduced every 100 cycles throughout the duration of the test.

D. Maintenance of the test doors shall be in accordance with the Draft Maintenance Plan.

E. If a failure or failures occur during testing, it shall be in accordance with the predictions given in the Reliability Plan. If the failure rate of any component falls under 500,000 cycles during the test, the part will be redesigned or replaced with a more reliable component, and the test repeated. If the redesigned component fails in less than 500,000 cycles, the test shall be deemed a failure and a design review with the Authority shall take place to determine the next steps.

F. The test shall be passed when 1,500,000 cycles have been completed with a Mean Cycles Between Component Failure (MCBCF) above 1,000,000 cycles.

6.07.03. Life Cycle Tests – Bridgeplates (OPTION)

A. The first bridgeplate shall be tested to 250,000 cycles. The requirements listed for the door test shall be followed for the bridgeplate testing.

B. Obstruction Detection shall be introduced every 100 cycles throughout the duration of the test.

C. Failures occurring during testing shall be approximately in accordance with Reliability Prediction. If the failure rate of any component falls under 85,000 cycles during the test, the part will be redesigned or replaced with a more reliable component and the test repeated. If the redesigned component fails in less than 85,000 cycles, the test shall be deemed a failure and a design review with the Authority shall take place to determine the next steps.

D. The test shall be passed when 250,000 cycles have been completed with a Mean Cycles Between Component Failure (MCBCF) above 170,000 cycles.

6.07.04. Network Testing

A. The door system supplier shall participate in Network and Vehicle Integration Testing described in T 16, Vehicle Monitoring, and T 24, Trainlines & Networks.

6.07.05. Door Panel Strength Tests

A. One of the first door panels shall be tested to ensure its strength is sufficient to withstand a load of 200 pounds (90.7 kg) applied over a 3 square inch (19.4 square cm) area. The load shall be applied perpendicular to the door panel surface, at the center of the span, at the leading edge of the panel, while supported only at the top panel hanger supports and bottom door guide edge. The maximum deflection of the panel shall be no more than 1/4 inch (6.4 mm), without permanent deflection.

6.07.06. Windows - ANSI Testing

A. A production door panel shall be fitted with a window and production glazing strip and tested for compliance to ANSI Z26.1, “American National Standard for Safety Glazing Materials for Glazing Motor Vehicles and Motor Vehicle Equipment Operating on Land Highways – Safety Code. Prior certifications will be considered for waiving this test requirement.

6.08: COMPONENT PRODUCTION TESTING

6.08.01. Passenger Door and Bridgeplate Production Testing

A. The Contractor shall prepare procedures for production testing of all production units. Procedures shall include functional tests of all features of equipment, including all safety devices, obstruction detection per T 06.06.05, and software setpoints. In addition, all doors shall pass a 100 cycle test. Procedures shall be submitted to the Authority for review and approval. [CDRL 06-17]

6.09: RELIABILITY

A. Reliability shall be measured and documented by the reliability Demonstration Plan detailed in T 02, Vehicle Design Requirements.

B. The Mean Distance Between Component Failures (MDBCF) for the carset of door operators and door controls shall be a minimum of 80,000 miles.

C. Mean Distance Between Component Failures for the carset of bridge plates and controls shall be a minimum of 80,000 miles. Bridge plate cycle count shall be utilized in the Reliability Demonstration Plan (OPTION).

6.10: MAINTAINABILITY

A. The door system shall not require routine maintenance more often than once per year. All adjustments of the door system and related components shall be performed with the use of locking hardware that will not loosen over time.

B. The door system shall be designed to allow replacement of individual components without requiring removal of adjacent components.

C. The PTU access port for diagnostic functions shall be readily accessible in the cab and at the door controller. Basic diagnostic functions shall be provided on the controller to diagnose problems without the use of the PTU.

D. The bridging mechanism, if provided, shall be readily accessible for maintenance and cleaning. The mechanism shall utilize a cartridge style construction, such that the entire assembly may be removed for maintenance and easily reinstalled.

E. Maintenance requirements shall be in accordance with the Authority's service intervals and the requirements of T 02.04, Maintainability.

F. The Mean Time To Repair the door system or bridgeplate shall be 30 minutes or less. Removal and Replacement of bridgeplate cartridge shall require no more than 60 minutes.

6.11: SAFETY

6.11.01. Door Safety

A. The door system performance, interlocks and safety features as described in this section shall be designed to operate in a failsafe manner to preclude injury to passengers and Authority personnel.

6.11.02. Bridgeplate Safety (OPTION)

A. The bridging device performance, interlocks and safety features as described in this section shall be designed to operate in a failsafe manner to preclude injury to passengers and Authority personnel.

B. Not used.

6.11.03. FMECA (Failure Modes Effects Criticality Analysis)

A. The Contractor shall provide a FMECA on the door and bridging device (OPTION) system control and circuits in accordance with a method allowed in 49 CFR 236 subpart H, appendices B and C. Authority review and approval shall be required. [CDRL 06-18]

B. See T 02.06, Safety, for FMECA requirements.

6.11.04. Compatibility

A. Wherever feasible, the door system components; operators, tracks, controllers etc. shall be fully interchangeable between Red and Orange Line cars.

6.12: CDRL ITEMS REFERENCED

CDRL 06-01, “Door Operator Design”, (Ref: T 6.02.04.J)

CDRL 06-02, “Door Locking”, (Ref: T 6.02.05.E)

CDRL 06-03, “Fail-Safe Microprocessor Control”, (Ref: T 6.02.06.A)

CDRL 06-04, “Door Controller”, (Ref: T 6.02.06.G)

CDRL 06-05, “Door Controller Diagnostics”, (Ref: T 6.02.07.C)

CDRL 06-06, “Door Panels”, (Ref: T 6.02.08.I)

CDRL 06-07, “Bridgeplate/Bridging Mechanism Design”, (Ref: T 6.02.10.I) (OPTION)

CDRL 06-08, “Operator’s Door Pushbuttons”, (Ref: T 6.03.01.G)

CDRL 06-09, “Door Control Schematics”, (Ref: T 6.03.02.J)

CDRL 06-10, “Passenger Door Pushbuttons”, (Ref: T 6.03.03.B)

CDRL 06-11, “Crew Switches”, (Ref: T 6.03.04.D)

CDRL 06-12, “Door Status Indicators”, (Ref: T 6.04.01.A)

CDRL 06-13, “Audio & Visual Door Closing Indicators”, (Ref: T 6.04.02.E)

CDRL 06-14, “Emergency Door Releases”, (Ref: T 6.05.01.D)

CDRL 06-15, “Door & Bridgeplate Qualification Test Procedures”, (Ref: T 6.07.01.A)

CDRL 06-16, “Door & Bridgeplate Qualification Test Results”, (Ref: T 6.07.01.B)

CDRL 06-17, “Door & Bridgeplate Production Test Procedures”, (Ref: T 6.08.01.A)

CDRL 06-18, “Door System FMECA”, (Ref: T 6.11.03.A)

6.13: REFERENCES

6.13.01. Standards Referenced

Americans with Disabilities Act, 49 CFR 27, 37, 38

APTA SS-M-18-10, Standard for Powered Exterior Side Door System Design for New Passenger Cars

49 CFR, Part 223, Safety Glazing Standards

6.13.02. Technical Specification Cross References

T 2, Vehicle Design Requirements
T 5, Operators Cab
T 8, Lighting
T 9, Power Distribution & Auxiliary Electric Equipment
T 10, Propulsion & Dynamic Braking
T 13, Communications & Passenger Information Systems
T 14, Interior & Exterior Appointments
T 16, Vehicle Monitoring System
T 18, Materials & Workmanship
T 20, Testing & Validation
T 24, Trainlines & Networks

PART T 07.00
HEATING, VENTILATION & AIR CONDITIONING

Table of Contents

7.01: SYSTEM DESCRIPTION & CONFIGURATION

7.01.01. General

A. The Heating, Ventilation and Air Conditioning (HVAC) equipment shall provide efficient and reliable vehicle interior climate control in all typical New England weather conditions. Reliability, in particular, is the primary Authority objective in regards to HVAC operation. Contractors are encouraged to suggest reliability improvements that will result in an increased Mean Distance Between Component Failure (MDBCF).

B. Vehicles shall be equipped with two roof-mounted, unitized HVAC units per car, associated duct work, diffusers and return air grilles. Two Operator's cab heater/side window defrosters shall be provided per cab. Baseboard radiant heaters shall be installed throughout the passenger area. Side door threshold heaters shall be incorporated under the door tracks

7.02: HVAC UNIT

7.02.01. HVAC Unit General Description

A. Two independently controlled, unitized HVAC units shall be installed on the roof of each car that provide continuous heating, ventilation and air conditioning to the cab and passenger area, with performance as detailed in this section.

B. Units shall be powered from the auxiliary power inverter as specified in T 9.05.

C. Units shall be housed in a stainless steel frame and enclosed by stainless steel covers that blend seamlessly with the contour of the roof skin. Alternative, corrosion resistant materials may be proposed for weight savings, subject to Authority review and acceptance.

D. not used

E. Condensate shall exit the HVAC unit through drain lines that terminate at the stainless steel roof pan. Drain valves shall be used to prevent air infiltration through the drain lines.

F. Drains in the roof pan shall funnel condensate (and rain water) through stainless steel drains that run through the car and terminate under the bottom of the underframe.

G. All motors shall be supplied with a safety ground strap connected to the HVAC unit frame.

H. All electrical components shall be provided in an enclosure mounted near the return air opening and accessible from the interior of the car. Components and enclosure shall fully conform to T 18, Materials & Workmanship, including, but not limited to sections covering wiring, electrical devices, microprocessors and software.

I. A detailed system functional description including dimensions and layout drawings shall be submitted to the Authority for review and approval. [CDRL 07-01]

7.02.02. Unit Installation

A. Stainless steel lifting eyes shall be an integral part of the stainless steel frame. Lifting eyes shall be balanced with respect to center of gravity, such that the four corner points of the unit contact the roof mounts simultaneously during installation. Installation shall not require tipping the unit. Supply air connections that require post-installation attachment may be proposed for Authority review and acceptance.

B. Lifting fixture and storage racks designed to allow 6 units to be stacked shall be supplied loose with the first cars. [CDRL 07-14]

C. Openings in the vehicle shall be limited to those required for return and supply air flow. Sealing gaskets included in the unit frame shall provide a weather proof seal between unit and carshell without the need for sealants or hardware. Supply air and return air roof flanges of the carshell shall be centered (within ±1/16 in (±1.59 mm)) on under-unit seals. Alternative installation techniques may be proposed for Authority review and acceptance.

D. Units shall be resiliently mounted to the roof of the car and bolted to carbody structural members. Resilient mounts may be omitted if the Contractor can demonstrate that vibration attenuation within the HVAC unit is sufficient to eliminate any noticeable transmission from the unit to the carbody.

E. HVAC unit covers (or a minimum 24 inch (610 mm) wide section down the longitudinal centerline of the cover) shall support a load of 300 pounds (1334 N) uniformly distributed over an area of 6 square inches (39 square cm). Screens shall be marked 'No-Step'.

F. Installed unit shall clear roof skin by a minimum of 1/2 inch (12.7 mm).

G. Hardware connections to the units shall be limited to mounting bolts, weather-proof, circular multi-pin connectors and a safety ground strap.

7.02.03. Air Conditioning Detailed Requirements

A. The unit shall be supplied with non-ozone depleting refrigerant for which a drop in replacement has been identified.

B. The air conditioning circuit shall be a hermetically sealed, scroll compressor based system.

C. Due to the unit height limitation, horizontal scroll compressors may be required. The HVAC supplier shall have a minimum of 100 passenger rail units in service, driven by the scroll compressors proposed for this application. Units shall have a minimum of 5 years in service and a record of satisfactory performance. Service history and proposed compressor make/model number shall be submitted for Authority review and approval. [CDRL 07-02]

1. Compressor manufacturer shall be approved by the Authority. .

2. Compressors shall be fitted with the following equipment, unless compressor manufacturer advises in writing that the components are not necessary/applicable for installation in this passenger rail air comfort system application:

   a. Oil level sight glass

   b. Crank case heater

   c. Discharge line check valve

D. Condenser motor(s) shall be rated for wash down duty applications with class H insulation, stainless steel shafts and sealed for life bearings. Motors shall be powered by a variable frequency inverter. Each Motor shall have a rating of at least 0.5 Horse Power (373 W).

E. After installation on the condenser shaft, condenser fan(s) shall be balanced to limit vibration to not more than 0.001 inch (.025 mm) peak-to-peak displacement in any direction.

F. Evaporator and condenser coils shall be copper tube construction per T 18, Materials and Workmanship. Coils may use coated aluminum fins. Coating shall be submitted to Authority for review and approval. [CDRL 07-03]

1. Evaporator coil shall be interlaced if more than one refrigerant circuit is provided.

2. Condenser coils shall be cross-flow.

3. Coils shall be housed in corrosion proof frames.

G. The circuit shall include solenoid valve(s), moisture indicators, filter dryers and over-pressure safety relief devices.

H. Expansion valves driven by sensing bulbs shall be provided, unless Contractor can demonstrate proven techniques to control superheat and sub-cooling utilizing capillary tubes, or similar method. Proposals shall be submitted for review and approval by the Authority. [CDRL 07-04]

I. Low and high pressure switches or transducers shall be provided, unless Contractor can demonstrate proven techniques to properly pump down evaporator coil and protect system from over pressure conditions. The over pressure safety relief device is not sufficient to meet this requirement. Proposals shall be submitted for review and approval by the Authority. [CDRL 07-05]

J. Drip pans shall be included under all condensing surfaces.

7.02.04. Overhead Heaters

A. Overhead heaters shall be nickel chromium resistance wires housed in a stainless steel frame. Stainless steel sheathed, finned-tubular heaters may be proposed for Authority review and acceptance.

B. Heaters shall be down-stream of the evaporator coil.

C. Heater output shall be continuously variable.

D. Duct sensors shall limit the supply air temperature to a maximum of 15°F (8.3°C) above return air temperature unless return air temperature is below 55°F (12.8°C).

E. For heater access, hinged access covers on the HVAC units shall be fitted with captive, quick release fasteners as well as a safety interlock switch that disables the open-coil heaters (if used) when the cover is opened.

F. See T 07.12, Safety, for over-temperature protection devices.

7.02.05. Evaporator Motor/Blower

A. Evaporator blowers shall provide ventilation continuously when a Master Controller in the train-set is energized (and 15 minutes after shutdown), including conditions that do not require cooling, heating or dehumidification or after a failure of the heating or cooling equipment.

B. Blower shall be directly driven by a dedicated AC motor.

C. Motors shall be Totally Enclosed, Non-vented (TENV), class H insulation with stainless steel shafts and sealed for life bearings. A keyway shall be provided to lock the squirrel cage(s) in position on the motor shaft.

D. The motor-blower assembly shall be balanced in accordance with Institute of Electrical and Electronics Engineers, Inc. (IEEE) Standard 11. Imbalance shall be less than 0.001 inches (.025 mm) peak-to-peak displacement in any direction.

   1. The motor-blower assembly shall be vibration-isolated, if required, to meet the vibration limits described in T 02.

7.02.06. Water Eliminators

A. Fresh air shall enter through automatic dampers and pass through water elimination devices that are designed to preclude the entry of snow, rain or sleet.

B. Water eliminators shall utilize a fine mesh stainless steel screen. Alternate techniques to remove fine snow or ice from fresh air intake may be proposed for Authority review and acceptance.

C. Eliminators shall be sloped to allow water to drain to the outside of the unit.

D. Water tests shall be conducted with HVAC units operational.

7.02.07. Air Dampers

A. Automatic fresh air dampers shall be provided to completely seal off the fresh air intake of the HVAC units.

B. All dampers on the car shall be automatically closed upon activation of a smoke detector. Dampers may be re-opened only after the smoke is no longer detected and a manual reset signal is received.

C. Dampers shall be closed during layover.

D. Dampers may be closed when the return air temperature is below 50°F (10°C) or above 80°F (29°C) to provide quicker warm up and pull down rates.

7.02.08. Smoke Detectors

A. Two smoke detectors shall be installed in the main air duct and located such that one is dedicated to each HVAC unit's supply air. Smoke detectors shall also be located in the fresh/return air mixing plenum of each unit. Alternate arrangements that provide the same level of protection may be proposed for Authority review and acceptance.

B. When smoke is detected, the smoke detector circuit shall automatically close the fresh air dampers, shut down the HVAC units, shut down blower motors, annunciate an audible alarm in the Operator's cab and cause a warning to be displayed on the Vehicle Monitoring System (VMS) screen.

C. The detectors shall not be too sensitive and detect cigarette smoke or similar, but shall detect smoke in such a concentration which can be considered a threat to passengers. The design shall include a press-to-test switch. The reset and press-to-test switches shall be in an approved location that is accessible to the crew and maintenance personnel and not visible to the passengers.

D. Smoke detectors shall be a transit service-proven design and meet UL 217 and EN 54-7/9 requirements. A list of Authorities using the selected devices shall be provided by the Contractor.

E. Smoke detectors shall be easily accessible from inside the train. Supply duct access panels with tamper proof screws shall be provided. Mixing plenum detectors shall be easily accessible through the return air grille. Wiring shall be through a connector on the smoke detector to allow easy removal and replacement.

F. Testing shall be performed to ensure that nuisance tripping is avoided. Details of the design, operation, installation, and test procedures of the alarm feature shall be submitted for approval by the Authority. [CDRL 07-15]

7.02.09. Temperature Sensors/Thermostats

A. Transit service-proven temperature sensors shall be thermistors encapsulated in stainless steel sheaths.

B. Ambient, return and duct air sensors shall be provided to meet the performance requirements of T 07.07, Performance.

C. Layover thermostat shall be a ruggedized, service-proven bi-metallic device with a setpoint appropriate to maintain the car interior temperature between 40°F (4.4°C) and 50°F (10°C). Alternative temperature sensing devices may be proposed for Authority acceptance.

D. Sensors shall be positioned and shrouded as required to prevent bias from other air flow sources.

E. Removal and replacement of the sensors shall take no longer than 10 minutes.

7.02.10. Air Filters

A. The unit shall be fitted with fresh and return air filters of a commercially available size. The filters shall be medium efficiency, Farr 30/30 pleated, or equivalent.

B. Filters shall be sized to limit replacement interval to 60 days or greater.

C. Fresh air filters shall be accessible from the vehicle interior.

D. Fresh air filter mesh shall be grounded, if required, to dissipate static charges.

E. To prevent condenser coil ingestion of leaves and other coil clogging residue, coils shall be fitted with stainless steel mesh-based high pass filters. Filter media and density shall be designed to prevent reduction in coil airflow. Filters shall be retained with over-center latches that allow easy access for removal, cleaning and replacement.

7.02.11. Drain pan

A. Drain pan shall be fabricated from stainless steel or equivalent corrosion resistant material.

B. Pan shall be sized to collect all evaporator coil, expansion valve or capillary tube condensate.

C. Pan shall be baffled to reduce sloshing and tall enough to ensure condensate is not spilled under any train acceleration, deceleration, grade or track superelevation.

D. Pan shall extend a minimum of 6" (152 mm) downstream of evaporator coil to ensure that any condensate entrained in the air stream is collected and returned to the drain pan.

7.02.12. HVAC Unit Insulation

A. A smoke/flame/toxicity compliant thermal insulation shall be installed on all surfaces in the evaporator section, including drain pan, suction lines, capillary tubes or expansion valves.

B. Acoustical insulation, if required to meet noise requirements of T 02, Vehicle Design Requirements, shall be identical to the type used on the air splitter and the belly pans located under the floor beams. Alternate types of acoustical insulation may be proposed, subject to Authority acceptance.

C. Thermal and acoustical insulation shall be compliant to T 18, Materials and Workmanship, for smoke, flame and toxicity.

7.03: HVAC CONTROLS

7.03.01. HVAC Microprocessor Controller

A. The HVAC controller shall automatically control interior vehicle conditions in accordance with requirements listed in T 07.07, Performance, and the Contractor's Temperature Control Matrix. The matrix shall include logic control of the floor heat system, threshold heaters, and fresh air dampers and shall be submitted for review and approval by the Authority. [CDRL 07-06]

B. The HVAC unit controllers shall be microprocessor based with flash memory

C. Microprocessors shall:

1. Allow for a ±5°F (2.8°C) setpoint adjustment in 1 degree increments for all switching points.

2. Allow adjustment of password protected software variables from the Portable Test Unit (PTU). Adjustments to variables may be configured by the Authority as temporary (buffer) adjustments. Permanent changes to the variables shall require an update to the software revision level, which will provide the Authority with the ability to easily verify identical settings throughout the fleet.

3. Store and process fault data in accordance with T 16.06.02, Subsystem Fault Recording.

D. Microprocessors shall be configured to provide communication between in-car HVAC units. Thermistor inputs from both units shall be used to determine the suitable mode of operation and appropriate output to the floor and threshold heater system. A Master-Slave arrangement is acceptable, providing units are fully interchangeable between car ends without modification, and a failure of one unit does not impact the functionality of the second unit. Communication failures shall not affect the functionality of either unit (units shall run independently).

E. If one unit fails, the second unit shall detect the failure. The operational unit shall then change modes or operational logic to compensate for the failure. The

Contractor's proposal for HVAC operation with only one unit functional shall be submitted for Authority review and approval. [CDRL 07-07]

F. Microprocessors shall be designed in accordance with T 17, Software Systems.

G. Software shall direct alternating usage of like components to balance the duty cycle of the components where practical. The software shall ensure a delayed start-up of one unit in order to limit inrush currents.

H. Troubleshooting and diagnostic functions as well as a self-test mode shall be accessible through the HVAC Portable Test Unit (PTU).

   1. The local access port shall be an industrial D coded M12 connector. The port shall be easily accessible through the return air grille.

I. See T 16, Vehicle Monitoring System for additional requirements.

J. The HVAC Controller graphical interface shall be designed to provide clear maintenance and diagnostic information, as well as current status and fault conditions. Screen shots shall be submitted for review and approval by the Authority. [CDRL 07-08]

7.03.02. HVAC Electrical Devices

A. All electrical devices provided for control of the HVAC system shall be in accordance with T 18.28, Electrical Devices & Hardware.

B. 600 VDC power to each HVAC unit shall be fed from a dedicated circuit breaker under the car to the main disconnect switch within the electrical box of the HVAC unit.

C. Low voltage DC power to each HVAC unit shall be fed from a dedicated circuit breaker in the cab or electric locker in the Non-Cab Car, as applicable, to the main disconnect switch within the electrical box of the HVAC unit.

D. All contactors, controls, current transducers, switches and additional electrical equipment required for local control of the HVAC unit shall be housed within the electrical locker located in the electrical box of the HVAC unit.

E. An AUTO-OFF-TEST switch shall be located on the face of the electrical locker, adjacent to the main power disconnect switch within the HVAC unit.

7.03.03. Current Transducers

A. Current transducers shall be used in place of air flow sensors for verification of blower motor current draw prior to energization of heaters or compressors. Alternate arrangements that serve the same purpose and provide high reliability may be proposed for Authority consideration.

B. Current transducers, or equivalent, shall be applied to the supply and return leads of the floor and overhead heat circuits. A difference in amperage will interrupt the circuit and disable the heaters. Contractor shall propose current differential threshold for ground fault detection and control scheme, including layover heat protection. Proposal shall be subject to review and approval by the Authority. [CDRL 07-09]

7.03.04. Car Controls & Communication

A. The HVAC controller shall provide temperature and HVAC fault indications for display on the VMS of active cabs. See T 16, Vehicle Monitoring System, for more information on requirements.

B. Self-test and fault logging records shall be accessible through the HVAC PTU.

C. Activation of the smoke detector will sound an audible alarm in the active cab(s) and flash on the Operator’s VMS screen.

D. The emergency HVAC Shutdown trainline signal for all HVAC units in a train-set shall be controlled by a switch on the Operator's console. Fresh air dampers shall also be closed when the Emergency HVAC Shutdown is activated. Units shall be designed to respond to trainline signal within 500 ms. Units shall return to normal, automatic temperature control when shutdown switch is returned to normal state.

7.04: OPERATOR'S CAB

7.04.01. Operator's Cab Heat

A. Operator's cab heat shall be provided by a thermostatically controlled cab heater located under each cab side window.

1. Heater shall be housed in a corrosion-resistant material.

2. Heater coils and blowers shall be powered by 230 VAC 3 phase.

3. Airflow shall be directed downward toward the floor and upward to defrost the cab side windows. Upward airflow to the cab shall exit through a diffuser that provides uniform flow across the width of the side window, adjustable through a damper. Downward airflow to the cab floor shall be through a screened outlet, also using a damper to adjust air volume.

B. Cab heater controls shall be located on the cab console and include:

1. An adjustable temperature control dial utilizing a color coded label. Dial shall control left and right cab heaters. Temperature setpoint shall be adjustable from vent-mode up to 80°F (27°C).

2. An OFF-LOW-HIGH rotary switch for air speed/volume control of both cab heaters.

a. Heater noise level in HIGH speed not to exceed 73 dBA, as measured at the centerline of the Operator seat, 3 feet (0.9 m) above bottom cushion.

3. See section T 07.12, Safety, for over-temperature protection devices.

C. Cab heaters shall be safety grounded to stainless steel bosses or tapping plates welded to the carshell.

D. The surface temperature of any cab heater components, including screen and diffusers, shall not exceed 125°F.

7.04.02. Operator's Cab Overhead Air Diffusers

A. A minimum of two satin-finished anodized aluminum air diffusers shall be supplied in the cab ceiling. A manually controlled, directional adjustment shall allow the air to be directed away from the operator.

B. Diffusers shall allow volume and directional adjustments by the Operator. A minimum of 400 Cubic Feet per Minute (CFM) (11.3 cubic-m per minute) shall be provided to the Operator's cab in the diffuser fully open position with the cab door closed.

C. A means to exhaust cab airflow shall be provided in the cab wall or cab door.

7.05: FLOOR HEAT

7.05.01. Baseboard Heaters

A. A natural convection baseboard floor heat system shall be installed along the sidewalls of the car.

B. Floor heaters shall be nickel chromium resistance wires housed in stainless steel or Inconel sheaths. Resistance wire shall be housed in a thermally conductive refractory material such as magnesium oxide. Aluminum finned tube, as manufactured under the trade name Calvane, or equivalent, may also be provided.

C. Heaters shall be arranged in two stages and powered from the 230 volt Auxiliary Inverter or 600 volt power third rail. Alternative pulse width modulation control of the floor heat may be proposed for Authority acceptance.

D. Heater elements shall be mounted on ceramic standoffs, or equivalent, to provide a high resistance to arcing or grounding under wet conditions.

E. Heater elements, heater guard and a portion of the sidewall shall be mocked up and tested to ensure that the temperature of any surface exposed to passengers does not rise above 125 °F (51.7°C) and that the sidewall insulation is sufficient to prevent a failure of the Heat Transfer Test (T 20.10.18).

F. Ground fault detection shall measure the supply and return heater amperages and be designed to shunt trip the circuit breaker if a differential exists. Contractor shall propose current differential threshold for ground fault detection to Authority for review and acceptance.

G. Refer to T 14.02.05, Floor Heater Grilles, for additional requirements.

H. Each individual heater enclosure shall be safety grounded to stainless steel bosses or tapping plates welded to the carshell.

I. Thermal insulation behind baseboard heaters shall provide the highest R value possible, since baseboard heaters are energized to determine the carbody conductivity (UA) value.

J. Alternate approaches for floor heating, such as in-floor heating elements, may be considered by the Authority. Contractor shall provide service proven history, repair procedure demonstrations and extended warranties for any proposed alternates.

7.05.02. Layover Heat

A. Layover heat shall be available whenever 600 VDC is available and a Master Controller in the trainset is not activated (after HVAC system 15 minute time-out).

B. A layover thermostat shall be provided to maintain interior temperatures between 40°F (4.4°C) and 50°F (10°C).

C. Heat in the layover mode shall be provided from a single stage of the baseboard heater system.

D. Layover heat shall be controlled on a per car basis.

7.06: AIR FLOW SYSTEM

7.06.01. Return air Grille

A. The return air grille shall be stainless steel or anodized aluminum and designed to prevent the accumulation of debris. Design shall be sight-tight with the use of louvers, or equivalent.

B. Grill shall be hinged on one side and fitted with captive, quick-release latches, a safety catch/cable. Grille shall be easily opened with an Allen wrench, or similar tamper resistant approach.

C. Return air filter shall be housed above the return air grille and easily removable.

D. Fresh air filters shall be easily removable and replaceable from the interior of the car via the return air grille.

E. Grille shall not be located in the cab ceiling.

F. Grille shall be sized to limit the return air flow velocity to less that 350 FPM (1.8 m/s).

7.06.02. Main Air Duct

A. Supply air shall be delivered down the entire length of the car, including the area under the HVAC units, through an insulated air duct fabricated from a corrosion-proof material. A diagonal splitter shall separate the air flow from both units.

B. A continuous ceiling height is preferred by the authority.

C. Flexible ducting, as required, shall be neoprene coated fabric meeting the smoke, flame and toxicity requirements of T 18, Materials and Workmanship. Alternative construction may be considered for review and acceptance by the Authority.

D. Ducting shall be fully insulated on all sides. The splitter shall be coated with smoke, flame and toxicity compliant sound deadening compound as manufactured by Daubert, or approved equivalent.

E. All ducting and air plenums shall be fabricated from non-combustible material per NFPA 130.

F. Supply air duct shall be sized to ensure the maximum air velocity is less than 1200 Feet per Minute (FPM) (6.1 m/s).

G. Filters shall be sized to ensure the velocity is 450 FPM (2.3 m/s) or lower.

7.06.03. Air Diffusers

A. Continuous, dual linear-slot air diffusers may be an integral part of the overhead passenger lighting fixtures described in T 14, Interior & Exterior Appointments.

B. Diffusers shall direct airflow towards the sidewalls as well as the center aisle.

C. Diffusers shall be anodized or powder coated aluminum extrusions that blend seamlessly with the ceiling panels and corner hatches.

D. The Pilot Cars shall be fitted with adjustable air diffusers to allow for air balancing. All remaining cars shall be non-adjustable after being fixed in accordance with the Pilot Car.

E. Air velocity anywhere in the car, 48 inches (1219 mm) above the floor and 6 inches below the diffuser, shall not exceed 50 FPM (0.25 m/s). Higher velocities within 6 inches of the ceiling or 6 inches of the sidewall are permitted.

7.07: PERFORMANCE

7.07.01. Interior Temperature Requirements

A. The HVAC system shall have sufficient heating and cooling capacity to maintain the following interior conditions in the cab and passenger area of the car:

	Ambient Temperature	Interior Average Temperature
1)	Below 0°F (-18°C)	Ambient temperature plus 66°F
2)	0 to 55°F (-18 to 13°C)	66-68°F (18.9-20.0°C)
3)	56 to 85°F (13.3 to 29.4°C)	68-72°F (20-22.2°C)
4)	86 to 92°F (30 to 33.3°C)	72-74°F (22.2-23.3°C)
5)	93 to 105°F (33.9 to 40.6°C)	Ambient temperature minus 18°F (10°C)
6)	Above 105°F (40.6°C)	Cooling - as system will provide

Table 7-1: Interior Temperature Requirements

B. The relative humidity in the interior of the car shall be maintained between 30-60% during all operating conditions, including periods when cooling or heating is not required. Humidity control shall be available in ambient temperatures as low as 45°F (7.2°C).

C. An interior pressure of between .06 - .15 inches water column shall be maintained at all times and at all vehicle speeds.

D. Vehicle interior temperature shall be within 3°F (1.6°C) of setpoint, 2 minutes after a 30 second door opening cycle (on one side) in worst case design conditions. See T 20, Testing & Validation, for Climate Room test requirements.

E. Temperature shall be consistent throughout the car. Stratification shall be limited to 4°F (2.2°C) within any vertical or horizontal plane. Stratification limits are detailed in T 20, Climate Room Testing.

7.07.02. Design Conditions

A. The conditions shown below are to be considered in the cooling calculations:

	Cooling Load	Requirement
1)	Ambient Temperature	91°F dry bulb / 73°F wet bulb (32.8°C dry bulb / 22.8°C wet bulb)
2)	Condenser air intake	100°F (37.8°C)
3)	Solar radiation	In accordance with ASHRAE Cooling Calculations Manual
4)	Passenger load	AW2 loading (all seats occupied and 3 sq-ft (0.279 sq-m) per passenger of standee area) 470 BTU/hr/passenger (138 W/passenger), Sensible Heat Ratio (SHR) of 55%
5)	Fresh air airflow	7.5 CFM (0.212 cubic-m per minute) per passenger at AW2 loading
6)	Interior electrical load	In accordance with Contractor's calculations
7)	Car Body Heat Transmission (UA value)	In accordance with Contractor's calculations, but no higher than value listed in T 02

Table 7-2: Design Conditions - Cooling

B. The conditions shown below are to be considered in the heating calculations:

	Heating Load	Requirement
1)	Ambient Temperature	8°F (-13.3°C)
2)	Solar radiation	None
3)	Passenger load	None
4)	Fresh air flow	7.5 CFM (0.212 cubic-m per minute) per passenger at AW2 loading.
5)	Interior electrical load	None
6)	Car Body Heat Transmission (UA value)	In accordance with Contractor's Calculations, but no higher than value listed in T 02

Table 7-3: Design Conditions - Heating

C. Detailed heating and cooling load calculations shall be provided for Authority review and approval. [CDRL 07-10]

7.08: COMPONENT QUALIFICATION TESTING

7.08.01. General

A. Prior to installation on the pilot car, the first HVAC units shall be qualification tested to ensure that the system performs in accordance with the specification and Contractor's load calculations.

B. Test procedures shall be submitted for Authority review and approval. [CDRL 07-11]

C. Test Reports shall be submitted for Authority review and approval. [CDRL 07-12]

D. Unit First Article Inspection (FAI) acceptance shall be subject to successful completion of all Qualification Tests.

E. The HVAC system supplier shall participate in Network and Vehicle Integration Testing described in T 16, Vehicle Monitoring System, and T 24, Trainlines & Networks.

7.08.02. Climate Chamber Facilities

A. Tests 7.08.03 through 7.08.11 shall be performed at an independent laboratory certified for HVAC unit qualification testing. Testing shall be in accordance with American National Standards Institute/ American Society of Heating, Refrigerating & Air Conditioning Engineers (ANSI/ASHRAE) Standard 37.

B. After successful completion of the unit testing the Pilot Car shall be shipped to an independent climate chamber facility. See T 20, Testing and Validation, for car level testing requirements

7.08.03. Fresh and Return Air Volume Test

A. Fresh, return and supply air flows shall be measured, with assumptions taken into consideration for vehicle duct static pressures. Fresh and supply air flow shall be equal to requirements of approved load calculations. Balancing devices, if required, shall be incorporated into the design at this time.

7.08.04. Cooling Capacity Tests

A. Cooling Capacity output of the unit shall be measured per the requirements of ASHRAE standard 37. Conditions for test shall be those listed in T 07.07.02, Design Conditions.

7.08.05. Refrigerant Charge Determination

A. The required refrigerant charge shall be determined after successful completion of the capacity test.

7.08.06. Condensate Carry-Over Test

A. Climate chamber shall be raised to 80°FDB (26.7°CDB), 75°FWB (23.9°CWB). System shall be run in normal operation for a period of 1 hour. No condensate shall blow off the coil. All condensate inside the unit shall be collected and removed via the drain pan. Condensate shall not form on any surface of the HVAC unit.

B. HVAC unit shall be slowly tilted fore and aft, and side to side to simulate worst case grade and track superelevation as well as acceleration and deceleration. Condensate shall be verified not to spill as a result of these conditions. Calculations for test angles to be included in the test procedure.

7.08.07. Temperature Control Matrix Verification Test

A. Return air and ambient air shall be varied throughout the range of conditions experienced in the Authority's operating environment. The temperature control matrix shall be verified through all modes of operation and all switching points.

B. System modulation and current draw from each component shall be evaluated to verify proper performance

C. The range of the setpoints shall be verified to provide a 5°F (2.8°C) adjustment, in 1 degree increments, for all switching points. Setpoints shall be accessed through the PTU. (7.03.01)

7.08.08. Maximum Operating Conditions Test

A. The ambient and condenser inlet air temperature shall be raised to 110 °F (43°C). Air conditioning shall still be available, at a reduced performance mode, if necessary.

7.08.09. High Ambient Temperature Operation Test

A. Ambient and condenser conditions shall be slowly raised above 110 °F (43°C) until the unit shuts down. Verification of an orderly, safe termination of performance shall be demonstrated.

7.08.10. Low Ambient Temperature Operation Tests

A. Ambient temperature shall be lowered to just above the compressor lock out temperature. Return air temperature shall be slowly lowered until the unit is running in partial cooling mode continuously. After one hour of operation, no evidence of coil freeze up shall be visible and adequate oil return to the compressor shall be verified.

B. If a low pressure switch is not utilized in the design, refrigerant charge shall be removed from the system until system is reduced to a low suction pressure (below 5 psi). Contractor shall verify that the coil has not frozen, oil return to the compressor is sufficient and the system has not been damaged under these conditions. Alternate approaches to demonstrate system protection under low pressure may be proposed for Authority consideration.

C. The condenser coil shall be completely blocked to ensure that the system is protected from high discharge pressure. The system shall shut down and automatically restart when pressures fall to normal levels.

7.08.11. Overhead Heat Capacity Test

A. The Overhead heat capacity shall be measured and recorded. The operation of the duct sensor shall be verified.

7.08.12. Heater Safety Tests

A. Heater shall be operated, while return air duct is slowly blocked. The over-temperature thermostat shall cycle power to the heaters without tripping the back up device.

B. Blower shall be disconnected and heater interlock with blower shall be jumpered, so that heaters remain on without air flow. The over-temperature thermostat shall cycle the heaters without tripping the back-up device.

C. Test B shall be repeated with the over-temperature thermostat jumpered. The fuse link or shunt trip device shall open the heater circuit before smoke or odor emanates from the unit.

D. If the unit is fitted with open coil-type heaters, the Contractor shall demonstrate that the access covers cannot be lifted without automatic power removal from the heaters.

7.08.13. Unit Cover Strength Test

A. A 300 pound (1300 N) load shall be uniformly distributed over an area of 6 square inches (39 sq-cm). No damage or cracking shall occur on the unit cover. No permanent deformation shall result.

7.08.14. Smoke Detector Test

A. Smoke shall be introduced to the fresh air inlet on the HVAC unit while the evaporator motor is running.

B. When smoke is detected, the microprocessor shall automatically close the fresh air dampers, shut down the HVAC units.

C. Outputs from the microprocessor shall be tested to ensure they energize (to sound an audible alarm and trigger a warning on the Operator's screen).

7.08.15. HVAC Communication & Failure Compensation Demonstration

A. Two units shall be connected as they would be in the car to demonstrate:

1. Coordination of temperature input based on the two unit's temperature sensors.

2. A failure of the communication and reaction of the two HVAC units to ensure neither unit shuts down.

3. After a simulated failure of one unit is introduced, the second unit shall detect the failure and change modes or operational logic to compensate for the failure.

7.08.16. Duty Cycle Testing

A. Alternating usage of like components to balance the duty cycle shall be demonstrated.

B. Hour meters shall be downloaded to the PTU for review by the Authority.

7.08.17. Disconnect Switch Verification

A. With 600 VDC and low voltage dc power energized and feeding the unit through multi-pin connectors, the main disconnect switch within the electrical box of the HVAC unit shall be thrown. Meters shall be used to ensure power has been safely interrupted. (7.03.02)

B. The functionality of the AUTO-OFF-TEST switch shall be demonstrated.

7.08.18. Interlock Verification Test

A. The blower motor current monitoring shall be disabled during HVAC unit operation. Shut down of the compressor and heaters shall be verified. A fault shall be triggered to the VMS.

B. Dropping out the evaporator contactor shall also disable the compressor and heaters.

C. The Condenser fan(s) shall be disabled to verify that the compressor shuts off.

7.08.19. Cab Heater/Side Window Defroster Tests

A. The cab heater shall be tested to ensure compliance with the heater safety tests of T 7.08.12, as applicable. Tests shall include blocking the air intake and disabling the blower motor.

B. In normal operation at room temperature, no surface of the cab heater shall rise above 125°F (51.7°C).

7.09: PRODUCTION TESTING

7.09.01. HVAC Unit and Cab Heater Production Testing

A. The Contractor shall prepare procedures for production testing of all production units. Procedures shall include functional tests of all features of each unit, including all safety devices, and shall be submitted to the Authority for review and approval. [CDRL 07-13]

B. Water testing per T 20 shall be performed on each HVAC unit with the evaporator fans in operation. Water shall not enter the unit or wick onto the air filters.

7.10: RELIABILITY

7.10.01. HVAC System

A. The HVAC units, floor heaters and cab heaters shall provide a Mean Distance Between Component Failures (MDBCF) in excess of 100,000 miles (161,000 km).

7.11: MAINTAINABILITY

7.11.01. Mean Time to Repair (MTTR)

A. The unit shall be removed and replaced in less than 1.5 man-hours.

B. The Operator's cab unit shall be removed and replaced in less than 30 minutes.

C. HVAC unit microprocessor shall perform self-diagnostic health checking of complete HVAC system. Diagnostics shall pinpoint failure down to Lowest Level Replaceable Unit (LLRU).

7.11.02. Accessibility

A. System shall be designed with maintainability in mind. All components shall be easily accessible or removable through hinged access covers.

B. The electrical compartment of the HVAC unit shall be easily accessible through the return air grille.

C. Line replaceable units shall utilize multi pin connectors, where practical, to facilitate quick removal and replacement.

7.12: SAFETY

7.12.01. Overhead Heater Safety Devices

A. In addition to software based protection schemes, over-temperature protection shall include:

1. A self re-settable thermostat(s) that disables control voltage to the heater contactors upon excessive temperatures.

2. Shunt trip circuit breakers shall be provided to open the heater circuit and protect the system in the event of a failure of the over-temperature thermostat(s).

3. Over-temperature protection devices shall not trip during normal shutdown of the system, or after a loss of 600V power.

7.12.02. Cab Heater Safety Devices

A. Over-temperature protection shall include:

1. A self re-settable thermostat(s) that disables control voltage to the heater contactors upon excessive temperatures.

2. A failure of the over-temp thermostat shall cause a manually resettable shunt trip breaker to open power to the heaters. The manual reset switch will be easily accessible.

7.12.03. Miscellaneous System Safety devices

A. Heaters and compressors shall be interlocked with the evaporator motor contactor.

B. Ground fault Indicators shall trip baseboard heaters in the event of a short to carbody.

C. Evaporator motor current transducer shall prevent energization of the heaters or compressors unless airflow is present.

D. Safety interlock switches shall be fitted to the HVAC unit access covers. If open coil-type elements are used, lifting of the cover shall disable power to the heaters.

E. HVAC unit electrical enclosure shall be fitted with a main power disconnect switch that allows the unit to be safely inspected and maintained.

7.13: COMPATIBILITY

A. not used

B. Where practical, HVAC component parts shall be interchangeable between vehicle types. HVAC unit frame and enclosure may differ due to clearance envelope limitations.

7.14: CDRL ITEMS REFERENCED

CDRL 07-01, “HVAC functional description and Layout”, (Ref: T 7.02.01.I)

CDRL 07-02, “Horizontal Scroll Service History”, (Ref: T 7.02.03.C)

CDRL 07-03, “Aluminum Fin Coating”, (Ref: T 7.02.03.F)

CDRL 07-04, “Requirement for Expansion Valves”, (Ref: T 7.02.03.H)

CDRL 07-05, “Requirement for Pressure Switches”, (Ref: T 7.02.03.I)

CDRL 07-06, “Temperature Control Matrix”, (Ref: T 7.03.01.A)

CDRL 07-07, “Single Unit Operation – Compensation Method”, (Ref: T 7.03.01.E)

CDRL 07-08, “Microprocessor Graphic Interface Screen Shots”, (Ref: T 7.03.01.J)

CDRL 07-09, “Ground Fault Protection - Heater Circuits”, (Ref: T 7.03.03.B)

CDRL 07-10, “Heating and Cooling Load Calculations”, (Ref: T 7.07.02.C)

CDRL 07-11, “HVAC Unit Qualification Test Procedures”, (Ref: T 7.08.01.B)

CDRL 07-12, “HVAC Unit Qualification Test Report”, (Ref: T 7.08.01.C)

CDRL 07-13, “HVAC & Cab Heater Production Test Procedures”, (Ref: T 7.09.01.A)

CDRL 07-14, “Lifting Fixture and Storage Racks”, (Ref: T 7.02.02.B)

CDRL 07-15, “Smoke Detector”, (Ref: T 7.02.08.F)

7.15: REFERENCES

7.15.01. Standards Referenced

ANSI/ASHRAE Standard 37, Methods of Testing for Rating Unitary Air Conditioning

ASHRAE Cooling Calculations Manual

IEEE Standard 11 (latest edition)

NFPA 130 (latest edition)

7.15.02. Technical Specification Cross References

T 02, Vehicle Design Requirements
T 09, Power Distribution & Auxiliary Electrical Equipment
T 14, Interior & Exterior Appointments
T 16, Vehicle Monitoring & Diagnostics
T 17, Software Systems
T 18, Materials & Workmanship
T 20, Testing & Validation

PART T 08.00
LIGHTING

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8.01: GENERAL

A. The lighting system consists of all interior lighting, exterior lighting and indicators. The design shall provide normal levels of lighting with a minimal degradation of color or luminosity over time. Safe levels of lighting shall be provided in the event of emergency conditions.

B. The lighting arrangement shall be developed by the Contractor and submitted to the Authority for review and approval, prior to the Preliminary Design Review. The design shall include:

1. Layout of the interior lighting, including emergency lighting. [CDRL 08-01]

2. Layout of the exterior lighting. [CDRL 08-02]

C. A sample of all light fixtures and control switches shall be submitted to the Authority for review and approval, prior to the Preliminary Design Review. [CDRL 08-03]

D. The lighting system shall meet the requirements of APTA Standards for car lighting as well as the requirements of this section. Where a conflict exists between this specification and the APTA Standard, the most restrictive condition shall apply.

8.02: SYSTEM DESCRIPTION & CONFIGURATION

8.02.01. Interior Lighting Passenger Area

A. The lighting fixtures shall use LED cluster modules, cool white in color, powered by the DC Low Voltage Distribution Network.

B. The lighting fixture's diffuser lens shall be translucent and shall provide a continuous lighting pattern. Sample options shall be provided for Authority acceptance.

C. The passenger main lighting fixtures shall be mounted in two continuous rows, one on each side of the aisle, as described in T 14, Interior & Exterior Appointments.

D. The main lighting in the passenger area shall be divided into three separate circuits, two for main lighting and one for emergency lighting. Each circuit shall have a separate circuit breaker. The lights attached to each circuit breaker shall be distributed throughout the car, such that loss of power from a single circuit breaker shall not darken one section of the car more than others.

8.02.02. Operator's Cab Lighting

A. Cab interior lighting, instrument lighting, and cab equipment compartment lighting shall use LED modules. The overhead lighting shall consist of two dimmable, directionally adjustable reading lights, one located on each side of the cab. The overhead lights shall be directed to avoid glare in the windshields. Refer to T 05.04 Operators Cab, Cab Equipment.

B. All indicators on the Operator’s console shall be colored LEDs. Refer to T 05.03, Operator’s Cab, Cab Controls, for details.

C. Cutout compartments, circuit breaker panels and equipment lockers shall be illuminated with LED lighting, controlled from the Operator’s console or automatically energized upon access panel opening.

8.02.03. Exterior Lighting

A. Headlights

1. Headlights shall be provided at the No.1 end of each car at locations approved by the Authority. The headlights shall provide high beam and low beam functions. Separate high beam and low beam lamps or dual filament lamps may be proposed.

2. The headlights shall by default be activated and remain ON in the lead car when a train direction is selected from any cab or hostler panel.

3. The low beam shall be angled down so as not to blind passengers on station platforms or Operators of approaching trains.

4. Headlamp electrical connections shall be protected from water ingress.

5. The Contractor may propose LED or High Intensity Discharge (HID) headlamps, proven in rail transit vehicles, to the Authority for consideration. Any alternative must support a high beam/low beam function.

B. Tail Lights and Marker Lights

1. Tail lights and Marker lights shall be provided at the No.1 end of each car, at locations approved by the Authority.

2. Tail and Marker light LED lamps shall be mounted in waterproof fixtures.

3. Tail lights shall be red LED lamps.

4. Marker lights shall be red LED lamps located above the windshields.

C. Body End Door Vestibule Lights

1. An overhead LED light shall be provided outside of each end door to illuminate the door apron area.

2. Refer to T 14, Interior & Exterior Appointments, for switching controls.

D. Step Lights

1. An LED light shall be provided at each loop step on the No. 1 end of each car.

8.02.04. Exterior Indicators

A. Exterior indicator lighting assemblies shall be set in waterproof enclosures. All bezels, hinges and trim shall be made of stainless steel, have captive stainless steel fasteners. All exterior indicator lights shall be LED clusters. Multiple indicators may be combined in one housing, as approved by the Authority.

B. All exterior indicators shall be located on the car sidewall, with the exception of the ATP Bypass Indicator Light. The height of sidewall indicators shall be near the top edge of the side doors. Location to be finalized at the mock up.

C. Parking Brake Light

1. A green Parking Brake LED light, visible in the transverse and longitudinal directions, shall be provided on each side of the car. The location shall be on the sidewall, adjacent to the first door leaf of the second door, or as approved by the Authority.

   a. The Parking Brake Light shall be illuminated whenever the Parking Brake is applied.

D. Propulsion Fault Indictor Light

1. The Propulsion Fault Indicator shall be a high brightness blue LED indicator light visible in the transverse and longitudinal directions. The indicator shall be provided on both sides of the car. The location shall be on the sidewall, adjacent to front door leaf of the first door, or as approved by the Authority.

E. ATP Bypass Indicator Light

1. The ATP Bypass Indicator shall be a high brightness (amber) LED light mounted on the front of the car, over the door or driver's windshield, as close as possible to the center line of the car. The ATP Bypass Indicator shall be lit at all times except when the ATP system is bypassed.

F. Snow Brake/Sleet Scraper Indicator Light

1. The Snow Brake/Sleet Scraper Indicator shall be a high brightness amber LED light and provided on both sides of the car. The location shall be on the sidewall, adjacent to rear door leaf, of the first door, or as approved by the Authority.

G. Door Summary Indicator Light

1. Each side of the car shall have a high brightness red LED indicator light that shall be activated whenever a door or bridgeplate the car is not closed and locked (See T 6.03.02). The LED shall project to the front and the back of the car in a longitudinal direction. The light shall also be viewable from the transverse direction. The location shall be on the sidewall, adjacent to the rear door leaf of the second door from the front of the car, or as approved by the Authority.

H. No Motion Bypass Indicator Light

1. Each side of the car shall have a high brightness red LED indicator light that shall illuminate whenever the No Motion Bypass switch is activated.

I. Exterior Door Leaf Status Indicator Lights

1. Each door leaf shall have a flush mounted red LED indicator light adjacent to the leaf on the side of the car. This light shall be active whenever the leaf is not closed and locked, or any bridge plate for that door is not retracted and locked. The Door Leaf Status indicator lights shall flash synchronously with the door chime. Refer to T 06.04, Passenger Doors & Controls, Door Indicators, for further information.

8.02.05. Interior Indicators

A. Interior Door Leaf Open Indicator Lights

1. Each car shall have flush mounted red Interior Door Leaf Open Indicator Lights, one located adjacent to each side door leaf, at approximately door header height. The Operation of the Interior Door Leaf Open Indicator Lights shall be the same as the Exterior Door Indicator Lights described above.

8.03: EMERGENCY LIGHTING

8.03.01. General

A. Emergency Lighting shall be powered from circuit breakers on the low voltage DC Bus. Emergency lighting loads shall remain powered when the Low Voltage Power Supply output is momentarily or continuously lost, with load shedding as described in T 09.08, Battery.

8.03.02. Emergency Interior Lighting

A. Emergency Interior Lighting shall be fully compliant with APTA RT-VIM-S-020-10 and use capacitive independent power sources.

B. The passenger area Interior Emergency Lighting shall be powered from a separate circuit breaker from the Main Interior Lighting. There shall be no load shedding of this circuit breaker or of Emergency Interior Lighting unless an independent power source is being provided. Emergency interior lighting shall remain powered at all times. At least 50% of lighting fixtures shall remain powered for emergency lighting.

C. The Operator’s Cab lighting, instrument lighting, and cab equipment compartment lighting shall also be powered from circuit breakers that shall remain powered during any interruption or loss of output from the Low Voltage Power Supply, with no load shedding.

8.03.03. Exterior Emergency Lighting

A. All exterior lights, including indicator lights, shall be powered from circuit breakers that shall remain powered after loss of the Low Voltage Power Supply.

B. Body end door vestibule lights will not be load shed.

8.04: LIGHTING CONTROLS

8.04.01. General

A. All lighting control switches and circuit breakers shall be located in the Operator's cab area or hostler panel area.

8.04.02. Passenger Area Interior Lighting

A. A switch shall be provided on the Operator's cab console to control main (non-emergency) passenger area lighting. This switch shall control the lighting trainline to illuminate main passenger lighting of all electrically coupled cars.

B. The trainline control for passenger interior lighting shall be designed so that the main interior lights may be turned on or off from any cab in a train, whether the Master Controller transfer switch is in the on position or not.

C. Cutout switches for passenger area lighting shall be located in the cab of the Cab Car. Cutout switches shall de-energize all interior lighting, including emergency lighting. Refer to T 05.03, Cab Controls.

8.04.03. Operator's Cab Interior Lighting

A. The overhead reading lights shall be controlled using a switch on the Operator's Console.

B. The cab equipment compartment lights shall be controlled from the cab equipment lighting switch on the Operator's Console (Refer to T 05.03, Cab Controls).

C. Overhead reading lights, equipment compartment lighting, and instrument lighting shall each have their own circuit breaker.

D. Dimmable white LED lights shall illuminate the cab gauges and instruments. The dimmer potentiometer and the control switch for instrument lighting shall be located on the Operator's Console. Refer to T 05.03, Cab Controls.

E. Hostler panel gauges and instruments shall be illuminated by white LED lights that are activated when the Hostler Panel access door is opened. Refer to T 05.05, Non-Cab Cars.

8.04.04. Exterior Lighting

A. Headlights

1. A separate circuit breaker shall be provided for the headlights.

2. The headlights shall be interlocked with the direction trainline, such that the headlights are illuminated on the lead car (forward or reverse from any cab).

3. A three position switch shall be provided for the high beam / low beam/ momentary off feature and shall be located in the Operator's Cab Console.

4. A 3-position headlight switch shall also be provided at the Hostler Panel on the Non-Cab Car.

B. Tail Lights, Marker Lights

1. The tail lights shall be illuminated at each uncoupled end. A separate circuit breaker shall be provided for the tail lights.

2. The marker lights shall be illuminated at each uncoupled end. A separate circuit breaker shall be provided for the marker lights.

C. Body End Door Vestibule Lights

1. Each body end door vestibule light shall automatically illuminate when the associated end door is opened.

D. Loop Step Lights

1. The loop step lights shall be illuminated at all times on the uncoupled ends of all cars.

8.05: LIGHTING PERFORMANCE

8.05.01. General

A. LED drivers shall not draw power when the LEDs lamps are off.

B. LED drivers shall operate reliably under conditions of the voltage levels and transients of the Low Voltage Distribution Network described in T 02.02.12, Low Voltage Power Systems.

C. LED light fixtures shall not adversely affect operation of any camera, inside or outside the car.

D. Control of LED currents shall not cause any noticeable light flickering.

E. LEDs should be driven by a constant current circuit with a setting not in excess of 65% - 70% of the LED maximum current rating.

F. Failure of a single LED shall not turn off the LED board and shall not reduce the life expectancy of the LED board.

G. The contractor shall submit to the Authority for review and approval the following information on the type of LED used in all lighting systems. [CDRL 08-04]

1. The LED color creation

2. The mean percentage of initial luminous flux available over the lighting system's expected operating hours

3. Heat management design

4. Total system light output degradation curve

8.05.02. Emergency Lighting Requirements

A. The interior and exterior emergency lighting shall be operational for 90 minutes after the loss of the Low Voltage Power Supply. If obtained from the car battery, load shedding as described in T 09.08, Battery, may be required. Interior emergency lighting levels may be allowed to drop as the battery discharges, but not below the level described in APTA RT-VIM-S-020-10, Standard for Emergency Lighting System Design for Rail Transit Vehicles.

8.05.03. Light Intensity Requirements

A. Interior Lights

1. General

a. To avoid discomfort from high light levels that reach the eyes directly or indirectly through reflections from shiny surfaces or from improperly shielded light sources, lighting equipment should be located as far from line of sight as possible.

2. Passenger Area

a. The average illumination intensity within the vehicle at elevations of 33 inches (838 mm) above the floor on a 45º plane centered on the front edge of any seat, and 55 inches (1400 mm) above the floor on a 45º plane shall be at least 35 foot-candles (377 lux). The average illumination intensity on the floor in the passenger aisles and passenger side door vestibule areas between the windscreens shall be not less than 20 foot-candles (215 lux).

b. The average illumination intensity on the end door threshold with doors open and passengers standing in the door vestibule must exceed 2 foot candles (21.5 lux) without any platform lighting.

c. Emergency interior lighting intensity levels shall be fully compliant with APTA RT-VIM-S-020-10.

3. Operator's Cab

a. The overhead lighting intensity shall be adjustable up to 25 foot-candles (269 lux).

b. Enclosure and circuit breaker panel lighting shall be sufficient to allow easy reading of all circuit breaker or switch identification, at night, with all other lighting turned off.

B. Exterior Lights

1. Headlights

a. The intensity and orientation of the high beam lights shall permit the Operator to see a dark object the size of a 50th percentile man 800 feet (244 m) ahead.

b. The high beam lights shall allow sufficient light to view a 50th percentile man wearing a reflective vest 1200 feet (366 m) away.

c. The low beam light shall strike the tracks at approximately 150 feet (45.7 m) in front of the car. It shall be positioned so as not to blind on-coming traffic or passengers when entering a station. The angle setting of the low beam light shall be finalized during the testing of the Pilot Cars.

2. Other Exterior Lights

a. The intensity of the loop step lights, handbrake lights and body end door lights shall be submitted for review and approval by the Authority. [CDRL 08-05]

3. Exterior indicators

a. All exterior indicators, when illuminated, shall be clearly visible from six cars away for those viewed in the longitudinal direction and minimum of 50 feet (15 m) for those viewed in the transverse direction.

8.06: TESTING

8.06.01. Component Qualification Testing

A. The Contractor shall demonstrate, for Authority approval, the ability of the lighting components to operate under the voltage ranges, power quality and transients described in T 02.02, Vehicle Design Requirements, Performance. (Previous successful tests of the same equipment may be submitted for approval). [CDRL 08-06]

8.07: RELIABILITY

A. The expected service life of LED interior lighting lamps shall be a minimum of 50,000 hours to 70% of original luminosity.

B. The expected service life for interior/exterior LED indicator, marker and tail lights shall be a minimum of 100,000 hours.

C. The expected service life of conditioning power supplies, if external to the lamp, shall exceed 200,000 hours. Mean time between failures for external conditioning power supplies shall exceed 200,000 hours.

D. The expected service life of headlamps shall be at least 1500 hours for the low beam and 1000 hours for high beam.

8.08: MAINTAINABILITY

A. Lighting fixtures shall be designed to facilitate cleaning of lenses, housing removal and LED lamp or module replacement. Additionally, all fixture covers shall be retained by hinges and held closed by a spring latch, tamper proof, self locking design. Lighting fixtures shall be dust-proof to minimize the accumulation of airborne dirt and dust inside the fixture.

B. Headlight fixtures shall be designed for quick removal and replacement of headlamps. Headlight replacement shall require no more than15 minutes and require no angular adjustment of the lamp.

C. The LED fixtures shall have wiring quick-disconnects and “snap-in” features to facilitate ease of removal without the use of special tools. LED fixtures shall be mounted securely in such a way that vibration cannot cause them to fall.

D. The lighting system shall comply with the maintainability requirements of T 02.04, Vehicle Design Requirements, Maintainability.

8.09: SAFETY

8.09.01. Safety Features

A. All lighting equipment shall:

1. Have an over-temperature protection with an automatic reset.

2. Withstand voltage fluctuations and shall not be damaged by the intermittent or continuous application of the reverse polarity DC power.

3. Be designed such that when disconnected, the powered side of the connection is covered.

B. Interior overhead lighting fixtures shall have a retaining strap to prevent them from falling on passengers or repair persons in case they come loose from their mounting.

C. Lighting fixtures located on the vehicle exterior and in the interior, below ceiling level, shall be watertight.

8.10: COMPATIBILITY

A. All lighting components shall be fully interchangeable between Red and Orange Line cars, to the maximum extent possible.

B. There shall be no discernable lighting performance differences between Red and Orange Line cars.

8.11: CDRL ITEMS REFERENCED

CDRL 08-01, “Drawing of the interior lights layout”, (Ref: T 08.01.B.1)

CDRL 08-02, "Drawing of the exterior lights layout", (Ref: T 08.01.B.2)

CDRL 08-03, "Light fixtures and control switches sample", (Ref: T 08.01.C)

CDRL 08-04, "LED data sheets", (Ref: T 08.05.01.G)

CDRL 08-05, "Miscellaneous Exterior Light Intensities", (Ref: T 08.05.03.B.2)

CDRL 08-06, "Component Lab Tests", (Ref: T 08.06.01.A)

8.12: REFERENCES

8.12.01. Standards Referenced

APTA RT-VIM-020-10, Standard for Emergency Lighting System Design for Rail Transit Vehicles.

8.12.02. Technical Specification Cross References

T 02 Vehicle Design Requirements
T 05 Operator's Cab
T 06 Passenger Doors & Controls
T 09 Power Distribution & Auxiliary Electrical Equipment
T 18, Materials & Workmanship
T 20 Testing & Validation

PART T 09.00
POWER DISTRIBUTION & AUXILIARY ELECTRICAL EQUIPMENT

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9.01: GENERAL

9.01.01. General

A. The auxiliary electrical system shall be rated for the performance cycles and parameters applicable to the operating environment of the vehicle as specified in T 02, Vehicle Design Requirements.

B. The design of the auxiliary power controllers shall be microprocessor based, utilizing Insulated Gate Bipolar Transistors (IGBT) as the switching devices.

C. The system shall consist of an Auxiliary Power Inverter (API) on each car to invert nominal line voltage to 230 volts, 60 Hertz, 3 Phase Alternating Current (AC). The 230 volt AC shall be transformed to 120 volts AC for convenience outlet use, windshield heaters, and any other approved devices. Each car shall have a Low Voltage Power Supply (LVPS) to convert the nominal line voltage to 37.5 VDC for battery charging and to energize the car's low level Direct Current (DC) power systems. The LVPS may be installed in the same enclosure as the API.

D. The Contractor shall submit a detailed functional description of the auxiliary power equipment and all associated components, including third rail power collection apparatus and High Speed Circuit Breaker, to the Authority for review and approval. [CDRL 09-01]

9.02: SYSTEM DESCRIPTION AND CONFIGURATION

9.02.01. Primary Power

A. The input third rail voltage shall be distributed for propulsion, Auxiliary Electrical Systems (including API and LVPS) and heater circuits, if applicable.

B. The sub-systems shall not be affected by rapid input power interruptions, such as created by ice, gaps in the third rail and third rail shoe bounce. The auxiliary electric system, both the API and LVPS, shall remain fully operational through all third rail gaps while the train travels at normal operating speeds.

C. The Contractor shall provide protection and filtering to protect the equipment in the event primary power voltage exceeds the ranges specified in T 02, Vehicle Design Requirements.

9.03: HIGH VOLTAGE COLLECTION AND RETURN

9.03.01. Third Rail Shoes and Holder Assembly

A. The third rail shoe assembly shall meet the geometric requirements of T 02.01, Vehicle Design Requirements, General. A sample shall be provided to the Authority for review and approval. [CDRL 09-02]

B. The Contractor shall submit the third rail fuse and shoe mounting arrangement to the Authority for review and approval.

C. Refer to T 11.04, Trucks, Traction Equipment for further details and requirements.

D. Insulated tools shall be provided to lift collector shoes off live third rail and secure (hang) the shoes in the lifted position. Design of the tools shall be submitted for review and approval by the Authority. [CDRL 09-03]

E. Two lifting tools and eight hangers shall be stowed in each cab. Refer to section 5.04.07, Special Tools.

9.03.02. High Voltage Current Return

A. The primary power returns shall be connected to fixed ground plates, not through the vehicle car body. Connections shall be per requirements of IEEE16 -2004, section 4.12.1.

B. The power return ground plate shall be isolated from the car-body, insulated for 3,000 volts minimum, and located for accessibility. It shall shall be grounded to all four axles through axle mounted ground brushes. The safety ground system of the car structure and trucks shall be separately grounded to the four axles of the car, through the axle mounted ground brushes.

C. Return cables and safety ground cables between car body and truck shall be designed and routed to reduce the electromagnetic interference from return currents and from capacitively coupled inverter currents circulating in the carbody and truck.

D. Refer to T 11.04, Trucks, Traction Equipment, for further details and requirements.

9.03.03. Ground Brushes

A. The Contractor shall provide ground brushes with low resistance ground return paths for the electrical system return. The ground brushes, returns and safety ground wiring shall be arranged in a manner that prevents passage of electrical current through the truck journal bearings and gear unit bearings. A minimum of two ground brushes shall be provided per axle.

B. The Ground brushes shall be sized to handle lightning discharge current according to International Electrical Committee (IEC) 61024-1-1:1993, for all but the worst 5 percent strikes repeatedly and the worst strike once, without failure. Cabling and grounding configuration shall be submitted to the Authority for review and approval. [CDRL 09-04]

C. The brush contact area shall have a current capacity sufficient to carry the worst-case duty cycle or fault current with half the ground brushes, per car or per truck, connected.

9.03.04. Ground Brush Assemblies

A. The ground brush assemblies shall be comprised of non-metallic, non-conductive housings with two spring-loaded brushes that bear against an axle ground ring. Axle mounted ground brushes shall be of a proven design in wide use in the rail transit industry. The axle ground ring shall be bronze or an Authority reviewed and accepted alternate material, and shall be pressed onto the axle. The ground brushes shall be mounted to allow for inspection without removal from the truck.

B. The brush and its holder shall be protected from mechanical damage, dirt and oil by a housing having an easily removable access cover.

C. Refer to T 11, Trucks, for further details and requirements.

9.04: HIGH VOLTAGE DISTRIBUTION

9.04.01. Shop Power

A. The Contractor shall provide and mount on each side of the vehicle an Authority standard shop power receptacle Nabson Part # 20605, in a location accessible from the side of the car with a weather resistant, spring loaded flip up cover hinged on the top.

B. The receptacles shall be electrically and mechanically interlocked such that when the shop power plug is inserted, power is routed to the auxiliaries and isolated from the third rail shoes and propulsion system. When the plug is removed, power shall be routed back to the third rail shoes and isolated from the shop power receptacle.

9.04.02. High Speed Circuit Breaker

A. The Contractor shall provide a High Speed Circuit Breaker (HSCB) of a single pole, bi-directional design in conformance with IEC 60077-3:2001. The HSCB shall be capable of isolating the propulsion system from the third rail primary power.

B. The HSCB shall provide the capability to interrupt full fault current. The HSCB shall be located downstream of the third rail shoes, shop power and auxiliary fuse connection, and upstream of the propulsion input line contactor and line filter. The HSCB opening shall be coordinated with the characteristics of the input filter and the rate-of-rise of the inrush current. Automatic reset of the HSCB is permitted. The Propulsion system shall have the ability to open or trip the HSCB. Refer to T 10.04.05, Line Contactor, for additional requirements.

9.04.03. Main Auxiliary Fuse

A. The Contractor shall provide a Main Auxiliary DC fuse mounted in a weather resistant enclosure to protect all Auxiliary DC circuits. The fuse characteristics shall be coordinated with downstream circuit protection devices. The fuse shall provide protection for faults that could occur between the fuse and the circuit protection devices.

9.04.04. Input Line Filter

A. The Contractor shall provide input line filter(s) to prevent ripple from being fed back into the line. The filter design shall limit the generated harmonics from each API or LVPS, such that total vehicle and train conductive emission are, under all conditions, below the levels specified in T 02.07, Vehicle Design Requirements, Electrical

Interference. The preferred design shall minimize the number of line filters required per married pair.

B. The line filter(s) for the API and LVPS shall be inductive above 40 Hz or less as required by T 02.07, Vehicle Design Requirements, Electrical Interference.

C. Where API and LVPS share a common Line Filter care shall be taken to dampen or limit any resonance that may occur due to lead lengths or individual smaller input filters on each unit.

9.04.05. API and LVPS Cutout

A. APIs and LVPS that share the same line filter shall be provided with separate cutout contactor to disconnect each unit from the line filter.

9.04.06. Auxiliary Distribution Enclosure

A. The Contractor shall provide a high voltage enclosure that contains all circuit breakers, contactors and fuses required for controlling the distribution of high voltage power to all auxiliary loads. The enclosure shall be located under the car in a location accessible from the side of the car. The Contractor shall submit the proposed location of the enclosure to the Authority for review and acceptance.

9.04.07. Protection Design

A. Fuses, circuit breakers, and current monitoring shall be coordinated with all subsystems to provide correct operation and protection. The Contractor shall ensure coordination, such that circuit interruption localizes the fault, protective devices act to back up the downstream devices, and that protective devices are capable of interrupting the maximum fault currents.

9.04.08. Cables and wiring

A. Cables and wiring shall be rated in accordance with IEEE STD1478-2001 for the expected design ambient temperature, humidity and vibration inside the enclosure. Conductors shall be sized based on the current-carrying capacity, mechanical strength, temperature, flexibility, and voltage drop. The Contractor shall comply with all wiring and cable requirements of T 18, Materials & Workmanship.

B. The Contractor shall meet the requirements of IEEE STD16- 2004 section 4.8.2.1, Circuit Separation and Electromagnetic Compatibility, regarding the routing of wires, the bundling of wires and the location of wires in the same enclosure.

9.04.09. Circuit Breaker and Fuse Identification

A. The Contractor shall provide identification for all fuses and electrical devices. Each circuit shall be individually protected by a circuit breaker or fuse.

9.04.10. Circuit Breaker Requirements

A. The Contractor shall supply circuit breakers that are molded case type, multi-pole with a frame size suitable for the continuous current interrupting duty. The handle shall indicate on, off and tripped positions and the breaker current rating shall be clearly and permanently visible after installation.

B. The Contractor shall use the ANSI C37.16 to determine and select the continuous current rating based on the load and type of service specified. The breakers shall conform to the requirements of ANSI C37.13 and ANSI C37.14.

9.04.11. Third Rail Protection

A. The auxiliary power system line contactors, and any other device that connects the third rail shoes to filters, that could keep the collector shoes energized, shall open whenever third rail current is absent as a result of a non-bridged third rail gap or de-energized third rail lasting more than 1 second. Refer to T 10.04, Propulsion & Dynamic Braking Major Components, Dead Rail detection and response time requirements.

9.05: AUXILIARY POWER SYSTEMS, DESCRIPTION AND CONFIGURATION

9.05.01. Auxiliary Power Inverter (API)

A. The Contractor shall provide for each car, a service-proven API with microprocessor-based control complying with the requirements contained in IEC 61287-1. The API waveform generation, output quality, component mounting, acoustical shielding, and other parameters shall be optimized to minimize audible noise.

B. The API control circuitry shall be completely independent of the LVPS. Failure of API control logic or API logic level low voltage power supplies shall not affect the operation of the LVPS.

C. The API shall operate from input primary power. It shall produce 230 VAC, 60-Hz, three-phase power for AC loads. The API AC output waveform produced shall operate all attached motors or electronic components without any adverse impacts on motors or equipment reliability, insulation or bearing life. It shall be the responsibility of the Contractor to coordinate motor ratings, with API output filtering design to ensure that that the above requirement is met. [CDRL 09-16]

D. The API conductive, inductive, and radiated emissions on the output and input sides shall not exceed the limits established in the Contractors EMC plan described in T 02.07

E. Galvanic isolation from DC line voltage shall be required for all equipment where passenger or operator contact is possible. The 120 volt convenience outlets, windshield heaters, and any other 120 VAC loads shall be transformer isolated and conform to IEEE Std. 1476-2000.

F. During start up, the fixed frequency API, shall ramp up voltage and frequency, maintaining a voltage/frequency ratio of 3.83 volts per hertz.

G. The Contractor shall coordinate the design of API with the primary power characteristics such that the API provides full rated performance over the third rail voltage range specified in T 02.02, Vehicle Design Requirements, Performance.

H. The API shall have an interface to the Digital Network defined in T 24, Trainlines & Networks. The API shall be PTU accessible through an industrial D coded M12 connector. .

9.05.02. API Cooling

A. Forced air, blown over the heatsinks and magnetics, shall be utilized for cooling. However, in no case shall the control electronics and power semiconductors be exposed to any external ventilation. The control electronics and power semiconductors shall be located in a dust tight, air tight, water tight enclosure. A small fan may be permitted to circulate air within the enclosure. Over-temperature protection shall be included and not prevent the cooling fans from cooling the unit.

B. . Intakes shall have centrifugal filters and baffles to precipitate the largest particles and prevent the ingestion of fine snow. Any replaceable filters used shall be easily accessible and designed for a 90 day replacement schedule. Drains shall be provided to remove any moisture that enters the duct system. Heat sinks shall be easily accessible for cleaning. Blower motors shall be protected from ingestion of dust.

9.05.03. API Capacity

A. Each API shall have a minimum of 10% excess capacity of the Married Pair load requirements described in 9.05.06.B, Load Shedding and Failover, when the other API has failed. The Contractor shall take into consideration the worst-case combinations of loads and inrush currents, as well as elevated under car temperatures in sizing the unit. During the starting of a heavy load, the API frequency and voltage output shall not exceed the specified ranges in T 02.02, Vehicle Design Requirements, Performance.

B. Other arrangements, such as providing a backup three phase or single phase inverter module, where the backup circuit is automatically switched in should the main circuit fail, may be proposed for consideration by the Authority if the Contractor can show through analysis and past experience that the availability of the API meets or exceeds the requirements described in T 9.05.03.A above. In such case, no load shedding shall take place.

C. The Contractor shall perform and submit a preliminary analysis of the API loads to confirm the inverter rating. This analysis shall be submitted to the Authority for review and acceptance. [CDRL 09-05]

D. The Contractor shall perform a final load flow analysis when all equipment loads are confirmed and shall submit a load report to the Authority for review and acceptance. [CDRL 09-06]

9.05.04. API Power Circuit Devices

A. The API shall utilize rail industry service proven IGBT devices. The API design shall be such that the maximum junction temperature of the power semiconductor devices shall be at least 10 degrees C below the manufacturer's maximum allowable junction temperature under the worst-case duty cycle and ambient temperature. Semiconductor module design shall take into account the effects of thermal cycling. Inverter design shall include sufficient junction temperature derating to provide reliable operation over a 30 year life cycle.

9.05.05. API Control

A. The API shall maintain operation and not shut down during input power interruption due to shoe bounce or ice accumulation on the third rail.

B. The input power cut-out contactor shall automatically open under high current fault conditions or other extreme abnormal events to permit automatic cut out of the API. The API control logic shall have the capability to open and close the input power cut-out contactor. The Contractor shall coordinate the opening of the contactor with the characteristics of the auxiliary fuse.

C. Cutout switches shall be provided in the cab of each Married Pair to manually cutout each API.

D. All control logic level hardware inputs and outputs for the API inverter shall be isolated to 1500 volts DC.

9.05.06. Load Shedding and Failover

A. The API load shed control shall determine whether primary power to a unit has been lost or an API has failed, and shall provide load shedding as appropriate.

B. An operational API in a car shall provide power to the fixed frequency equipment in an adjacent car in the Married Pair in the event the adjacent car's API fails. Load shedding will be allowed during API failures to allow performance critical equipment to remain fully functional on both cars. Performance critical equipment shall include the air compressor, propulsion inverter cooling fans, cab heaters / windshield defrosters, and any other equipment necessary to maintain the operation of the vehicle. HVAC units shall also be powered, but can be load shed by operating only 1 of 2 HVAC units per car. Load switching between API's under such failures shall be automatic and shall prevent both API's from supplying power to the same equipment simultaneously should the failed API restart.

9.05.07. Load Management

A. Starting and restarting of the AC loads shall be coordinated with the design of the API to prevent extended delays and overloading of the API. The Contractor shall submit details of the load management function to the Authority for review and approval. [CDRL 09-07]

9.05.08. 230 VAC/120 VAC Power Distribution

A. The Contractor shall provide circuit breaker panels and circuit breakers for all 230 volt and 120 volt loads powered from the API. Circuit breakers shall comply with the requirements of T 18, Materials & Workmanship.

B. The 230 VAC/120VAC distribution panel shall have space for 1 additional 3 phase 230 VAC circuit breaker and one additional single phase 120 VAC circuit breaker. The panel shall be located in the electrical locker or the cab back wall.

C. 230 VAC Power used for any application such as cab heat where passenger or crew safety is involved shall be provided through a 230 VAC isolation transformer with a Wye connected secondary and a grounded neutral. All circuits attached to the Wye connected secondary shall be separately ground fault protected.

9.05.09. Convenience Outlets

A. The 120 volt AC output of the API shall be provided through standard duplex outlets with spring-loaded hinged covers. The outlets shall be protected by a GFCI circuit breaker in the distribution panel. The locations of the duplex outlets shall be as described in T 14.02.23 and T 5.04.05, Convenience Outlets.

9.06: LOW VOLTAGE POWER SUPPLY

9.06.01. General

A. Two independent LVPS shall be provided per married pair. The LVPSs shall provide 37.5 VDC battery charging and all low voltage power requirements.

B. The two LVPS in the Married Pair shall share the 37.5 VDC load of the Married Pair.

C. The LVPS shall be a DC to DC isolated switching design. The low voltage power system shall normally operate at all times. The LVPS output shall be current limited. The output shall be protected to prevent backfeed from the battery or the other LVPS in the event of an internal failure in a single LVPS.

D. The LVPS may share a common line filter with the API. However, each LVPS shall have independent control logic and control logic power supplies from the API. The LVPS shall continue to function in the event of an API failure.

E. The LVPS shall provide low voltage power to all car systems, power all lights, charge the battery, and power other essential loads as determined during the course of the vehicle design. The Contractor shall submit the efficiency versus load analysis for the DC switching converter to the Authority for review and approval. [CDRL 09-08]

F. The LVPS shall have an interface to the Digital Network as defined in T 24, Trainlines & Networks.

G. The LVPS shall also have a local access port for PTU connection, utilizing an industrial D coded M12 connector. .

9.06.02. Cooling

A. Forced cooling of externally mounted LVPS heat sinks is preferred. Forced air may be blown over the heatsinks and magnetics. However in no case shall the control electronics and power semiconductors be exposed to any external ventilation. The control electronics and power semiconductors shall be located in a dust tight, air tight, water tight enclosure. A small fan may be permitted to circulate air within the enclosure. Over-temperature protection shall be included.

B. The LVPS design shall be such that the maximum junction temperature of the power semiconductor devices shall be at least 10 degrees C below the manufacturer's maximum allowable junction temperature under the worst-case duty cycle and ambient temperature. Semiconductor module design shall take into account the effects of thermal cycling. Inverter design shall include sufficient junction temperature derating to provide reliable operation over a 30 year life cycle.

C. Intakes shall have centrifugal filters and baffles to precipitate the largest particles and prevent the ingestion of fine snow. Any replaceable filters shall be easily accessible and designed for a 90 day replacement schedule. Drains shall be provided to remove any moisture that enters the duct system. Heat sinks shall be easily accessible for cleaning. Blower motors shall be protected from ingestion of dust.

9.06.03. Low Voltage Power Supply Capacity

A. The two LVPS in a married pair share the full load of the married pair including battery charging. In case of an LVPS failure the remaining active LVPS shall have sufficient capacity to carry the entire married pair low voltage DC load indefinitely under the worst case ambient conditions defined in T 2, Vehicle Design Requirements, without suffering any damage or reduction of reliable life.

B. Other arrangements, such as trainlining low voltage power, may be proposed for consideration by the Authority if the Contractor can show through analysis and past experience that the availability of Low Voltage Power meets or exceeds the requirements described in T 9.06.03.A above.

C. The float charge current and battery voltage and battery temperature shall be monitored and both LVPS voltage outputs shall be regulated to maximize battery life and servicing intervals.

9.06.04. LVPS Control

A. The LVPS shall start automatically when the steady-state high voltage input is between the ranges specified in T 02.02, Vehicle Design Requirements, Performance. The LVPS shall respond to transient conditions in a manner fast enough to prevent damage or degraded performance.

B. The input power cutout contactor shall automatically open under high current fault conditions or other extreme abnormal events to permit automatic cut out of the LVPS. The LVPS control logic shall have the capability to open and close the input power cut-out contactor. The Contractor shall coordinate the contactor opening with the characteristics of the auxiliary fuse.

C. Cutout switches shall be provided in the cab of each Married Pair to cutout each LVPS individually.

D. All LVPS control logic level hardware inputs and outputs shall be isolated to 1500 volts DC or greater.

E. Both LVPS units shall monitor battery temperature and charging current and shall coordinate to regulate battery voltage within the battery manufacturer's requirements for the measured battery temperature.

F. The Contractor shall provide a dead battery start-up feature for the LVPS. The dead battery start feature shall permit automatic dead battery start-up whenever the input primary power is within the limits specified in T 02, Vehicle Design.

9.06.05. Load Shedding

A. An output sensing device shall detect the loss of the low voltage dc output from an LVPS.

B. The LVPS load shedding controls shall determine whether primary power has been lost or an LVPS is not operational, and shall provide appropriate load shedding to maintain essential loads. If only one of the two LVPS units is not operational in a Married Pair vehicle, no load shedding shall be required. The remaining LVPS unit shall be capable of operating indefinitely in this condition.

C. For a total loss of input power to a vehicle or loss of output from both LVPS units, load shedding is permitted.

D. If the loads were shed due to loss of primary power, automatic reconnection shall occur when the LVPS input power contactor closes.

E. Load shedding based on low input voltage as opposed to total loss of primary power shall not be allowed without review and acceptance by the Authority.

F. Interruptions of power for less than 15 seconds shall not cause an initiation of load shedding.

9.07: LOW VOLTAGE DISTRIBUTION

9.07.01. Low Voltage Distribution Panels

A. The Contractor shall provide Low Voltage Distribution Panels (LVDP) for all low voltage distribution circuits in each car. The LVDPs shall be provided with space to add 2 additional circuit breakers. The LVDP shall conform to the requirements of T 18.28, Electrical Devices and Hardware.

B. The LVDP shall be conveniently located within each car. In the cab car, the LVDP shall be located in the cab. Each non cab car LVDP shall be equipped with a substantial, self-latching door that shall be opened using an Authority crew key. The location and lighting provided for the LVDP shall conform to the requirements of T 05.04, Cab Equipment and T 08, Lighting.

C. Low voltage DC circuits shall include all circuits powered from the Low Voltage Power Supplies and the battery.

9.07.02. Low Voltage Circuit Breakers

A. A Circuit breaker shall be provided for each low voltage circuit. The circuit breaker shall be identified to indicate the circuit it protects.

B. The circuit breaker rating shall be sized for the current capacity of branch circuit wiring and load requirements. A minimum of ten percent of the total number of circuit breakers shall be provided as spare spaces.

9.07.03. Wiring, Clearance and Over Voltage Protection.

A. Electrical circuits and associated cabling shall be designed with clearance and creepage distance between voltage potentials and between vehicle body ground. Design for clearance and creepage shall consider the environmental conditions to which the circuits and cabling will be exposed. The Contractor shall comply with the requirements of IEEE STD16-2004 section 4.7

B. The maximum wiring voltage drop, including returns, between a power source and any on car loads shall be less than 4 volts. The wiring and cabling shall comply with all requirements in T 18 Materials & Workmanship.

C. The Contractor shall provide protection from over-voltages as defined in 4.4.3.5 and 4.4.4 of IEEE STD1476-2000.

9.07.04. Low Voltage Bus Bar

A. The battery main and return bus plates shall be housed in weather resistant, dust-proof enclosures, complete with readily removable gasket access covers for maintenance. The battery return bus plates shall be insulated from the car-body. The returns and negative connection from the battery and the LVPS shall be connected to a common negative bus bar. The low voltage system shall be grounded at one and only one point on each car.

B. The grounding of the low voltage system shall be designed and implemented in a manner that take into account potential differences between cars caused by traction return current flows. Trainline circuits shall be immune to worst case potential differences between cars.

9.08: BATTERY

9.08.01. General

A. Each vehicle shall be equipped with a nickel-cadmium-alkaline battery. Other battery technologies may be proposed for Authority review and acceptance. The battery shall be float charged using the LVPS DC output voltage. Both LVPS units shall monitor battery temperature and charging current and shall regulate voltage within the battery manufacturer's requirements. The Contractor shall provide load calculations for the battery loads. The Contractor shall submit to the Authority for review and approval, a load analysis, including load profiles, operating conditions, de-rating factors and other parameters for battery sizing. [CDRL 09-09]

B. Nickel Cadmium (NiCd) batteries shall have a minimum manufacturer's rated life of 15 years.

C. The battery shall be designed to withstand the severe mechanical shock of the transit environment. It shall meet or exceed the shock requirements of IEC 61373 and the shock and vibration requirements of T 02.01, Vehicle Design Requirements, General. The battery supplied shall have a record of proven service in rail transit applications.

D. Battery cells shall be designed for low or no water consumption.

E. The battery case shall be clear or translucent, shock resistant (IEC 61373) and flame retardant, with low smoke emissions meeting the requirements of UL94V-O.

F. The car battery shall be capable of operating under the angular displacement conditions described in APTA RT-S-VIM-020-08, Section 8.

9.08.02. Battery Capacity

A. The battery shall have the capacity to supply all low voltage power loads listed in the Emergency Load Schedule and maintain voltage within equipment operating limits, in the event no output is available from either LVPS.

B. A discharge rate beyond the rating of the battery shall not permanently damage the cells or reduce the battery's capacity.

C. Complete discharge of the battery shall not permanently damage the battery.

D. Emergency Load Schedule

Subsystem	**0 – 30 min**	**30 – 60 min**
Door control	Normal cycling	2 cycles
Door indication lights	X	-
Interior lighting	Emergency	*
External Indication Lights	X	-
Headlights	X	-
Marker and Tail Lights	X	X
End Door Vestibule Lights	X	X
Cab instrumentation, circuit breaker and cutout panel lighting	X	X
Parking Brake Light	X	X
Train Radio	X	X
Passenger Emergency	X	X

Intercom		
Crew Intercom	X	X
Public Address	X	X
Exterior Destination Signs	-	-
Interior LED Signs	X	-
LCD Monitors (OPTION)	-	-
Networks	X	X
Propulsion/Braking control	X	-
Operators console and controls (radio, wipers, buzzer, etc.)	X	-
Horn control	X	-
Air compressor controls	X	-
Event recorder	X	X
CCTV	X	X
Vehicle Monitoring System	X	-
ATP/ASR System	X	-
Master Controller	X	X
Other essential functions as determined during vehicle design and reviewed and accepted by the Authority	X	X

* After 30 min the emergency interior lighting shall continue using its separate supercapacitor based power supply as described in T08, Lighting.

E. If Low Voltage Power is unavailable due to loss of primary power from the third rail (for more than 15 seconds), the load shedding shall maintain loads starting with the 30 minute to 60 minute schedule.

F. The Contractor shall submit an Emergency Load Shedding Schedule to the Authority for review and approval and shall update the document as the design progresses. [CDRL 09-10]

9.08.03. Battery Box

A. The batteries shall be mounted on a single stainless steel pull-out tray. Batteries shall be housed in an enclosure located below the car floor, in a manner that permits installation and maintenance servicing from the side of the car. The interior box coverings shall be of an approved glass fiber reinforced polyester resin. The box enclosure shall have ventilation openings to prevent and remove any gas build ups. The enclosure shall have an accessible drain plug. The drain plug shall be held in place by means of a cotter pin or a chain.

B. The battery cover shall be attached to the battery box sides with an Authority accepted mechanical arrangement. The battery cover shall open to permit full access to the battery compartment without requiring cover removal. The roll-out tray shall have a positive lock, that when properly secured shall prevent the tray from moving. The Contractor shall submit the battery enclosure and pull-out tray to the Authority for review and approval. [CDRL 09-11]

9.08.04. Battery Protection

A. The Contractor shall provide a battery system with an approved over-temperature protective method to protect the battery, battery enclosure, and other car components from damage resulting from battery overcharging.

B. The temperature sensor shall be located to prevent nuisance trips.

C. A double pole battery circuit breaker shall be mounted in an environmentally protected enclosure under the car and as close to the battery as possible. This breaker shall incorporate a shunt trip device and disconnect the battery from car wiring when the battery temperature is excessive.

D. The circuit breaker shall be rated to withstand the short circuit capacity of the battery and shall be connected into the B+ and B- leads from the battery terminals.

9.09: DIAGNOSTICS, FAULT LOGS AND INTEGRATION WITH THE VEHICLE MONITORING SYSTEM (VMS)

9.09.01. Self Diagnostic

A. The API and LVPS shall incorporate a self-test feature to verify that all system components are operating within normal limits. The API and LVPS controllers shall initiate a self-test upon start up.

B. The Contractor shall submit information on all self-test functions to the Authority for review and approval.[CDRL 09-12]

9.09.02. Fault Logs

A. The API and LVPS fault logging capabilities shall meet the requirements of T 16, Vehicle Monitoring System. The Contractor shall provide all documentation for the API and LVPS required by T 16.07, Fault Management Description.

9.09.03. Laptop Portable Test Unit (PTU)

A. The Contractor shall provide the necessary software to allow a laptop Portable Test Unit (PTU) to connect to the API and LVPS. Using a laptop PTU, maintenance personnel shall be able to run diagnostic routines, full self-tests and access full fault logs and snapshot data on each API and LVPS. The PTU software shall also support making configuration changes and uploading software upgrades.

B. API and LVPS software changes may only be made locally through the PTU access port.

9.09.04. Snapshots

A. The LVPS and the API shall have ability to record, configure and retrieve event triggered snapshots of selected parameters as described in T 16.06, Vehicle Monitoring System, Subsystem Integration and T 16.07, Fault Management Description.

9.09.05. Vehicle Monitoring System Integration

A. The auxiliary electrical system shall report all faults to the Married Pair Vehicle Monitoring Unit (VMU). The API and LVPS units shall be capable of transferring additional fault data and system parameters to the VMU upon request.

B. The LVPS and API units shall fully comply with the Fault Management Plan and system integration requirements of T 16.07, Fault Management Description.

C. The LVPS and API systems shall comply with the Network integration requirements and Network Integration Document of T 24, Trainlines & Networks.

9.10: PERFORMANCE

9.10.01. Low Voltage Regulation

A. The LVPS shall maintain battery charging voltage within the battery manufacturer's recommended voltages based on battery temperature over the entire range of the line input voltage specified in T 02, Vehicle Design Requirements.

9.10.02. Power Quality

A. The LVPS shall limit the voltage peak to peak ripple to 3 percent or less of nominal output voltage level, even with the batteries disconnected.

B. The droop characteristic shall be limited to 1 volt, from 20 percent load to full load.

C. The LVPS shall not permit an output transient response to exceed ±10% of nominal voltage for any step load change. The maximum overvoltage shall not exceed 44.0 VDC.

9.10.03. API Regulation

A. Steady-state voltage regulation shall maintain API output voltage within ±5% over the entire range of connected loads and over an input voltage range specified in T 02, Vehicle Design Requirements.

B. The steady-state frequency regulation shall maintain an API frequency of 60 Hz, ±2 Hz. The system shall be designed to maintain a phase-to-phase voltage imbalance of 1% or less.

C. The API AC output voltage waveform shall not exceed 5% total harmonic distortion.

D. The voltage or frequency shall return to a steady-state value within two seconds after an input voltage step change of 100 volts or a 50% step change in the output current.

9.10.04. Efficiency

A. The efficiency of the API and the LVPS shall be at least 70% over the output power range of 20% to 50% of full load.

B. The efficiency of the API and the LVPS shall be at least 85% over the output power range of 50% to 100% of full load.

9.10.05. Battery Capacity

A. The Battery shall meet the requirements of all tests of IEC 60623. The Battery shall meet the capacity requirements of T 9.08.02 under all temperature conditions starting from a fully charged battery.

9.11: TESTING

9.11.01. General

A. Prior to installation on the pilot car, the first API and LVPS units shall be qualification tested to ensure that the systems perform in accordance with the specification and contractor's load calculations.

B. Test procedures shall be submitted for Authority review and approval. [CDRL 09-13]

C. Test Reports shall be submitted for Authority review and approval. Unit First Article Inspection (FAI) acceptance shall be subject to successful completion of the Qualification Tests. [CDRL 09-14]

9.11.02. Battery Tests.

A. Batteries shall be given a capacity test at the point of manufacture, in accordance with APTA RP-E-007-98 1999 and results shall be submitted to the Authority for review and approval. The Battery shall be type tested to prove it meets the capacity requirements of T 9.08.02.

9.11.03. Auxiliary Power System Test

A. The Auxiliary Power System, including, API and LVPS units shall be qualification tested in accordance with IEC 61287-1, including the sudden variation in load test (4.2.6) and effectiveness of filter test (2.4.6.5c).

B. The Contractor shall also verify proper coordination between the two LVPS units and proper battery charging under all load and primary power conditions.

9.11.04. Noise Test

A. The Contractor shall perform a vehicle noise test per IEC 61133.

9.11.05. Transient Over-voltage Test

A. The Contractor, in addition to the transient overload protection provided by the supplier, shall ensure that all equipment powered from the third rail is compliant with and tested to meet the transient over voltage requirements of IEC-61287-1, Section 2.1.1.9d, Supply Line Over-Voltages.

9.11.06. Power Return Tests

A. The Contractor shall perform static tests of the power return circuits and safety grounding bonding in accordance with IEC- 61133.

9.11.07. VMS Integration Test

A. The API and LVPS shall comply with the VMS integration testing requirements of T 16.19, Vehicle Monitoring System, Performance, and with the Network Integration Tests of T 24.07, Trainlines & Networks, Performance.

9.11.08. EMI Testing Requirements

A. The Contractor shall verify that the resonant frequency of all auxiliary and HVAC input filters, under worst case conditions of temperature, tolerance and aging, is in compliance with requirements of T 02.07 Vehicle Design Requirements, Electrical Interference.

B. The Contractor shall verify in Power Lab tests that the API, LVPS and HVAC inverters conductive and inductive emissions do not exceed their allotted portion of the allowed total vehicle or train emissions defined in T 02.07, Electrical Interference. The limits shall be met under all conditions, including failures, such as loss of phase on auxiliary motors.

C. For each line side conductive emission test, the impedance of the 600 VDC source, the distance from the source to the test location, and the values of the line filter components shall be measured and recorded.

D. All Auxiliary Inverter output voltage and current harmonics shall be measured under all loads and input voltages and shall be shown to meet the requirements of the Electromagnetic Compatibility Plan and harmonic requirements of the attached motors.

9.12: RELIABILITY

9.12.01. Mean Distance Between Failures

A. The API & LVPS systems shall achieve a combined Mean Distance Between Component Failures (MDBCF) of 150,000 miles or greater.

9.12.02. Service Life

A. The batteries shall have a minimum rated rail service life of 15 years.

B. Ground brushes shall have a minimum life of 100,000 miles (160,934 km).

C. Ground brush rings shall have a minimum life of 1,000,000 miles (1,609,340 km).

9.13: MAINTAINABILITY

9.13.01. General

A. The API & LVPS diagnostic monitoring shall permit verification of the proper operations of the hardware during troubleshooting and testing.

B. The Contractor shall ensure that all filters and screens are replaceable in less than 10 minutes.

C. The Contractor shall comply with the maintainability design requirements of T 02.04, Vehicle Design Requirements, Maintainability.

D. The Contractor shall meet the requirements of the Maintainability Demonstration and Pilot Train Maintainability Demonstration described in T 02.04, Vehicle Design Requirements, Maintainability.

9.14: SAFETY

9.14.01. Safety Labels

A. All cabinets and panels shall be provided with internal and external warning labels that indicate the maximum circuit voltage used in the cabinet or panel.

B. Suitable warning labels and or warning devices of an approved design shall be provided for filter capacitors.

C. The outside cover of the main switch enclosure shall contain a high voltage warning label.

9.14.02. Safety Discharge

A. Bleeder resistors shall be provided to discharge the filter capacitors to less than 50 volts within 3 minutes when disconnected from line voltage.

9.14.03. Safety Grounding

A. All equipment on the vehicle shall be safety-grounded to the vehicle structure. Equipment boxes and enclosures shall be grounded as specified in this Section. This car safety grounding shall be distinct from power return grounding.

B. Safety ground and return wiring design shall be coordinated with the truck design to ensure that all bearings are protected against stray current flow.

C. The car structure shall not be used as a normal circuit return path for any electrical equipment.

9.14.04. Failure Mode, Effects, And Criticality Analysis

A. The Contractor shall perform a Failure Modes Effect and Criticality Analyses (FMECA) on all Auxiliary Power System circuits required to prevent current discharge into a dead rail. [CDRL 09-15]

B. The Contractor shall perform the emissions safety analysis for the API and LVPS inverters specified in T 02.07, Vehicle Design Requirements, Electrical Interference.

9.15: COMPATIBILITY

9.15.01. Shop power

A. The vehicle shop power receptacle supplied by the Contractor shall be fully compatible with existing shop power plugs in service on Authority's Red and Orange Line maintenance facilities

9.15.02. Grounding

A. The grounding methods and routing shall be the same for both the Red and Orange line vehicles.

9.15.03. Capacity

A. Auxiliary electric equipment capacity shall be sized to be sufficient for both Red and Orange Line applications. All parts shall be interchangeable.

9.16: CDRL ITEMS REFERENCED

CDRL 09-01, “Auxiliary Functional System Description”, (Ref: T 09.01.01.D)

CDRL 09-02, “Sample Third Rail”, (Ref: T 09.03.01.A)

CDRL 09-03, "Insulated Collector Lifting Tool" (Ref: T 09.03.01.D)

CDRL 09-04, “Grounding Configuration”, (Ref: T 09.03.03.B)

CDRL 09-05, “Preliminary Load Analysis”, (Ref: T 09.05.03.C)

CDRL 09-06, “Final Load Analysis”, (Ref: T 09.05.03.D)

CDRL 09-07, “AC Load Management”, (Ref: T 09.05.07.A)

CDRL 09-08, “LVPS Efficiency versus Load analysis”, (Ref: T 09.06.01.E)

CDRL 09-09, “Battery load Calculations”, (Ref: T 09.08.01.A)

CDRL 09-10, “Battery Load Shed Schedule”, (Ref: T 09.08.02.F)

CDRL 09-11, “Battery Enclosure and Pull out Tray”, (Ref: T 09.08.03.B)

CDRL 09-12, “Self-Test Functions”, (Ref: T 09.09.01.B)

CDRL 09-13, “Test Procedures”, (Ref: T 09.11.01.B)

CDRL 09-14, “Test Reports”, (Ref: T 09.11.01.C)

CDRL 09-15, “Dead Rail Protection FMECA”, (Ref: T 09.14.04.A)

CDRL 09-16, “Coordination of API output waveform and AC loads”, (Ref: T 09.05.01.C)

9.17: STANDARDS REFERENCED

IEC 61133 2006 Railway applications – Rolling stock – Testing of rolling stock on completion of construction and before entry into service

IEC 61373, Railway Applications - Rolling Stock Equipment - Shock and Vibration Tests

IEC 61287-1 2005 Power converters installed on board rolling stock – Part 1: Characteristics and test methods

ANSI/IEEE C37.13.1-2006 Standard for Low-Voltage AC Power Circuit Breakers used in Enclosures

ANSI/IEEE C37.14-1979 American National Standard IEEE Standard for Low-voltage DC Power Circuit Breakers Used in Enclosures

ANSI/IEEE C37.16-2000 Low-Voltage Power Circuit Breakers and AC Power Circuit Protectors Preferred Ratings, Related Requirements, and Application Recommendations

ANSI/IEEE 1476-2000 Standard for Passenger Train Auxiliary Power Systems Interfaces

APTA RP-E-007-98 1999 Recommended Practice for Storage Batteries and Battery Compartments

IEC 60077-3:2001 Electric equipment for rolling stock - Part 3: Electro technical components - Rules for d c. circuit-breakers

IEC 61024-1-1:1993 Protection of structures against lightning

9.18: TECHNICAL SPECIFICATION CROSS REFERENCES

T 02, Vehicle Design Requirements
T 05, Cab Equipment
T 08, Lighting
T 14, Interior & Exterior Appointments
T 16, Vehicle Monitoring System
T 18, Materials & Workmanship
T 20, Testing & Validation

T 24, Trainlines & Networks

PART T 10.00
PROPULSION & DYNAMIC BRAKING

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10.01: SYSTEM DESCRIPTION

10.01.01. General

A. Each axle shall be driven by a 3 phase self-cooled AC induction traction motor through a gear unit. Power to the traction motors shall be provided and controlled by inverters utilizing Variable Voltage, Variable Frequency (VVVF) three-phase AC vector control. The power converter semiconductor switching devices shall be Insulated Gate Bipolar Transistor (IGBT) technology. Two independent inverters shall be provided to obtain control on a per truck basis.

B. The propulsion system's brake chopper shall provide control for electrical energy delivered to the braking resistors and to the third rail as regenerative energy. In normal operation regenerative braking shall have priority over rheostatic braking. The electric braking shall be available when speed is above 1 mile per hour (1.6 km/hr).

C. Interchangeability of propulsion equipment between red and orange line vehicles is encouraged to the greatest extend practical.

D. The Contractor shall submit a propulsion functional system description to the Authority for review and approval. [CDRL 10-01]

10.02: INSTALLATION

10.02.01. Equipment Installation

A. The propulsion system inductors, capacitors, electronic controls, contactors, power devices, etc shall be housed in water tight enclosures installed under the vehicle. Each inverter shall be independent of the other, but may share a common sealed enclosure.

B. The Contractor shall provide propulsion system enclosures with top hinged removable covers. The covers shall be secured when closed with spring loaded latches.

C. The propulsion under vehicle wiring or cabling shall be protected from debris damage.

D. Not used

E. All equipment installation shall be in compliance with all Authority requirements for safety as defined in this section and T 02.06, Vehicle Design Requirements, Safety. All equipment shall be in compliance with the maintainability requirements of this section and T 18, Materials & Workmanship and T 02.04 Vehicle Design Requirements, Maintainability.

F. Braking resistors shall be installed in a location and orientation on the vehicles such that braking currents induce the minimum rail to rail voltage under the vehicle.

G. The braking resistors shall be isolated from their frames and their frames isolated from the vehicle-body with insulators.

10.02.02. Motor Installation

A. Each traction motor shall be resiliently mounted in the truck. Safety hangers shall be incorporated into the design.

B. Not used.

C. All traction motor leads shall be installed and routed to minimize induced rail to rail voltage under the vehicle.

D. Connection of traction motor cables from each axle to the vehicle-body shall use a watertight quick disconnect arrangement. No on-truck direct connections between traction motors or between ground brushes shall be used.

E. Carbody and truck safety ground cables shall be separate from current return cables as described in T 09.03, Power Distribution & Auxiliary Electrical Equipment.

F. Wires, cables, and hoses connecting between trucks and vehicle-body shall be routed to minimize flexing movements.

G. A splined or keyed, taper fit flexible coupling shall be provided between traction motor and gear unit shafts. The coupling shall be designed to withstand maximum torque, torque reversals, shocks, vibrations, and misalignment encountered during performance of the worst-case duty cycle.

10.03: PROTECTION

10.03.01. Propulsion System Equipment

A. The Contractor shall protect the propulsion system from damage and incorrect operation by protective functions including but not limited to the below listed items. The Contractor shall submit to the Authority for review and approval a description of each propulsion protection concept including system response or action taken. [CDRL 10-02]

1. Motor overload

2. Motor over temperature

3. Reverse connection of motor leads

4. Short circuit

5. Ground fault

6. Charging and braking resistors open circuit

7. Inverter over temperature

8. Inverter charging current inrush outside limits

9. Transient voltages

10. Line contactor failure

11. High inverter ripple current

12. Loss of phase

13. DC circulating current in excess of limits

14. Brake resistor high temperature

15. Open or shorted motor phase

16. Gear unit failure

17. Speed sensor failure

18. Blower motor failure

10.04: MAJOR COMPONENTS

10.04.01. Inverter

A. All traction inverters shall be alike and interchangeable.

B. Not used.

C. Not used.

D. Each inverter's control logic shall be housed in the same enclosure with the inverter.

E. The power semiconductor assemblies shall be functionally grouped, keyed and mounted in a modular manner.

F. Insulated Gate Bipolar Transistors (IGBT) shall be used in static power control circuits. The control shall be such that the maximum junction temperature of power semiconductor devices shall be at least 10 degrees C below the manufacturer's maximum allowable junction temperature even under the worst duty cycles defined in T 02.02, Vehicle Design Requirements, Performance.

G. Filter capacitors shall be in accordance with IEC 61071. The current inrush to the filter capacitors during initial charging shall be limited to a value that shall not damage or adversely affect the system.

H. The Contractor shall use low inductance bus bars to limit switching losses.

I. The Contractor shall submit inverter equipment layout for Authority review and acceptance. [CDRL 10-03]

10.04.02. Inverter Cooling

A. Heat generated by power semi-conductor devices shall be dissipated by heat sinks. . Forced air shall be blown only over external heat sinks fins and not used to cool active or passive components.

B. Not used.

C. Temperature sensors shall be provided and continuously monitored. Any fault detected shall be reported to the Vehicle Monitoring Unit (VMU).

D. The ventilation system shall remove dirt, snow and water from the cooling air. The air inlet openings for the inverter ventilation system shall be located at the side of the vehicle at the floor line and shall include a protective screen designed to prevent accumulation of debris. The screen shall be easily removed to facilitate cleaning.

E. Inverter heat sinks shall be easily accessible for cleaning.

F. Blower motors shall be protected from the ingestion of dust.

G. A blower fault shall result in reduced performance of the inverter in order to avoid damage of the equipment.

10.04.03. Blower Motors

A. The Contractor shall provide and use only transit rail service proven blower motors. The blower motors shall operate from 230 VAC power provided by the vehicle's auxiliary power system. The blower and motor bearings shall not require lubrication and shall be of a sealed design. The Contractor shall submit selected blower motors to the Authority for review and approval. [CDRL 10-04]

10.04.04. Input Filter

A. The Contractor shall use the combination of an inductor or inductors and capacitors to form a filter to absorb transients. The line filter inductor may be air or iron core and shall be suitably shielded and oriented under the vehicle to minimize inductive coupling with running rails and track circuits. The line filter design shall prevent ripple from feeding back into the line and shall protect the inverter from line transients. The line inductor may be located external to the inverter housing provided all electromagnetic emissions requirements are met.

B. The input filter shall meet or exceed all requirements for operating under the voltages and transients described in of T 02.02.10, Supply Voltage.

C. The Contractor shall supply a charging contactor and a charging resistor to critically damp the charging circuit and to limit charging current. Charging current shall not exceed 500 amps per car.

D. The Contractor shall provide an automatic test of line filter capacitance at each power up.

10.04.05. Line Contactor

A. The Contractor shall provide a line contactor for each traction inverter container. The line contactor shall separate the inverters from the line in cases of over current, over voltage, and unbridgeable rail gaps. The line contactor shall also open if the substation ripple voltage is not present. If a common line filter is used for both inverters, separate cutout contactors shall be provided to disconnect each inverter from the line filter in case of an inverter or motor fault. Self cutout shall be provided in case of inverter or motor fault.

B. The line contactor(s) shall have an arc chute. The arc chute's design shall take into consideration the need to prevent build up of ozone in the compartment.

C. The Contractor shall provide a line contactor with a minimum design life of 2,000,000 operations. The Contractor shall provide a line contactor that opens within 150 milliseconds from control logic output request.

D. In the event of high voltage or current interruptions, the propulsion system shall have the capability to trip the High Speed Circuit Breaker (HSCB). The propulsion logic shall be programmed to reset the HSCB a maximum of three times before the HSCB must be manually reset. After 3 resets propulsion logic may not reset the HSCB until the lockout is cleared by the PTU. Refer to T 09.04 Power Distribution & Auxiliary Electrical Equipment, for additional requirements of the HSCB.

10.04.06. Braking Resistors

A. The Contractor shall provide dynamic brake resistors that are edge-wound ribbon expanded metal, or stamped metal type or an Authority reviewed and accepted equal. Brake resistors shall be designed to meet braking performance requirements per T 02.02 Vehicle Design Requirements, Performance. If brake resistors are mounted under car they shall also be designed and arranged in a manner to minimize inductive emissions.

B. Cooling shall be by natural convection. The braking resistor design shall conform to IEC60322 Rules for ohmic Resistors Used in Power Circuits of Electrically Powered Vehicles. The Contractor shall submit the brake resistor type and design for Authority review and approval. [CDRL 10-05]

C. The resistors shall have the capacity to provide all necessary power dissipation during operation with rheostatic-only dynamic braking over the complete Orange and Red Lines with passenger loadings up to, and including AW3.

10.04.07. Ground Brushes

A. Refer to T 09.03, High Voltage Collection and Return.

10.04.08. Odometer

A. The propulsion system shall have the ability measure vehicle mileage. Isolated outputs shall be provided to drive an electromechanical odometer located in the vehicle cab.

10.04.09. Speed Sensors

A. Speed sensors, encoders or other speed sensing system shall be provided to determine the speed of each traction motor; speed sensor locations shall be submitted to the Authority for review and approval. [CDRL 10-06]

B. The speed-sensor mounting arrangements shall be identical to permit complete interchangeability between the Red and Orange Line vehicles and require no mechanical adjustments. All speed sensors shall be easily accessible for inspection and replacement purposes.

C. Speed sensors shall be connected to the car-body by shielded, flexible cable terminated in a keyed waterproof, multi-pin connector to facilitate truck removal.

D. Each sensor shall provide a positive indication of vehicle motion down to 1 mph or less. The sensors mounting arrangement shall be such that the direction of vehicle motion can be determined. The output pulsed wave forms from the sensors shall be supplied to the propulsion control logic as a logic input.

E. not used

10.04.10. Dead Rail Sensing

A. The Contractor shall provide a sensing circuit design that can detect a dead rail or unbridgeable section gap by means of substation ripple detection or other approved method.

B. All input filters and contactors, etc. that could keep the collector shoes energized shall disconnect from the line when third rail current ceases for more than 1 second as a result of an unbridgeable third rail gap or de-energized third rail. The propulsion system shall inhibit regeneration of power into the rail within 250 milliseconds of dead rail detection.

10.05: TRACTION MOTORS

10.05.01. General

A. A 3-phase self ventilated squirrel cage type induction motor with gearing shall be provided. All traction motors shall be alike and interchangeable.

B. Traction motors shall comply with IEC 60349-2.

C. Traction motors shall be thermally rated for operation under the normal and degraded continuous duty cycle requirements of T 02.02, Vehicle Design Requirements, Performance, even with worst case wheel diameter variation. Under these duty cycles the traction motors shall not exceed temperature rise limits of one class lower than the class of insulation provided.

D. Traction Motors shall be designed to perform towing duty cycles defined in T 02.02, Vehicle Design Requirements, Performance, without exceeding insulation ratings for temperature rise. These requirements shall be met with worst case wheel diameter variation.

E. The motors shall be self-ventilated with input screens to prevent the ingestion of debris.

F. The Contractor shall supply a motor with a history of service proven successful operation.

10.05.02. Motor and Rotor Balance

A. The traction motor rotor cage shall consist of copper alloy bars with brazed or welded rings. Traction motors shall be dynamically balanced to meet the requirements of National Electrical Manufacturers Association (NEMA) MG 1-12.06 and IEEE 11-13.2.2. The rotors shall have a net dynamic unbalance less than 1.0 inch ounce (7 mN*m). The rotor and rotor cooling fan may be balanced together or separately.

10.05.03. Motor Insulation

A. The Contractor shall provide motor stator coils that have been vacuum pressure impregnated. The insulation material shall conform to requirements contained in IEEE 11, for a Class H insulation system or greater.

B. The Contractor shall ensure that dust, water and fine snow do not impact the performance of the motor insulation system.

C. The Authority will consider resins that will be fully effective and shall not result in Authority tank contamination. In all cases the insulating resin provided in the Vacuum Pressure Impregnation (VPI) process shall be service proven and submitted to the Authority for review and approval. [CDRL 10-07]

D. Motor winding shall be designed to minimize voltage stress from short IGBT voltage rise times.

E. The motor insulation system shall be rated to withstand the voltage stresses of IGBT inverter duty.

10.05.04. Load Sharing

A. The traction motors shall permit performance characteristics, including duty cycle rating, to be met with variations in wheel diameters of up to 1/4-inch (6.4 mm) between axles on a truck.

10.05.05. Bearings

A. Traction motors shall be provided with sealed bearings that have American National Standards Institute/ Anti-Friction Bearing Manufacturers Association (ANSI/AFBMA) L 10 rating life equivalent to at least 1,000,000 miles (1,609,500 km) of service. Bearings shall be designed to prevent deterioration due to capacitively coupled stator/rotor currents caused by short inverter rise times.

10.05.06. Emission limits

A. Motors shall be designed to meet inductive emission limits, as specified in T 02.07 Vehicle Design Requirements, Electrical Interference, without the use of external shielding.

10.05.07. Motor Connections

A. The Contractor shall utilize proven traction motor cable termination and fixation methods. The selected method shall be subject to Authority review and approval. [CDRL 10-08]

10.05.08. Traction Motor Ventilation

A. The motor air inlet openings shall include a protective screen. The screen design shall be such that air flow shall not be restricted by snow, ice, leaves and debris. No filters shall be used. The contractor may propose a totally enclosed self cooled motor provided that all duty cycle requirements of T 02.02, Vehicle Design Requirements, Performance, are met.

10.05.09. Traction Motor Temperature Monitoring

A. The Contractor shall monitor the motor temperature using calculations based on the winding voltage and current measurements. The Contractor may propose other valid thermal modeling methods to the Authority for review and acceptance as part of the design review process. In the event these measurements result in an indication of motor over temperature, the propulsion system logic shall have the ability to react by inhibiting electric braking and or removing inverter power from the motors. A method to lock out propulsion after a predetermined number of over temperature incidents, shall be proposed and reviewed at design review.

10.06: GEAR UNITS

10.06.01. General

A. Each motored axle shall be driven by a parallel gear unit.

10.06.02. Mounting

A. The gear unit shall be mounted on the axle and supported by a resilient mount on the truck transom.

10.06.03. Gear Inspection

A. The Contractor shall provide an oil-tight inspection cover on the housing for visual inspection of the gears, removable and accessible with the gear box installed on the vehicle.

10.06.04. Seals

A. All seals on rotating parts shall be of the labyrinth type.

10.06.05. Gears

A. Helical gears shall be provided. The gear unit shall be designed for bidirectional service. The gear ratio shall be selected to meet the performance specified in T 02.02, Vehicle Design Requirements, Performance.

B. Gears shall be designed to require minimal inspection and adjustment and shall have a minimum fatigue design life of 1,000,000 miles (1,609,500 km) with no degrading of performance.

C. The gears shall be fabricated from high-quality gear steel heat-treated/hardened in accordance with American Gear Manufacturing Association (AGMA) 140.01 gear material manual.

10.06.06. Bearings

A. The gear unit shall be equipped with tapered roller bearings or Authority reviewed and accepted equivalent. Bearings shall have an ANSI/AFBMA L10 rating life equivalent to 1,000,000 (1,609,500 km) miles or more of service.

10.06.07. Lubrication

A. The gear unit shall be oil-lubricated using an Authority approved SAE 80W90 lubricant compliant with G L5MIL-L_2105C. The gear unit shall have the oil capacity to provide cooling within the design limits.

B. The gearbox shall have at least one oil drain opening with magnetic plug, located at the lowest point in the case or sump, and an easily accessible means of measuring oil level. The Contractor shall provide a magnetic filler plug.

10.07: ELECTRICAL BRAKING AND FRICTION BRAKE INTERFACE

10.07.01. Electric Braking

A. The propulsion system shall provide electric braking whenever braking is requested and vehicle speed is greater than 5 miles per hour (8 km/hr), and maintain it down to 1 mph (1.6 km/h).

10.07.02. Regenerative Braking

A. The propulsion control system shall monitor the line voltage continuously to determine line receptivity. When the line is receptive and braking is requested, the electrical brake control shall automatically supply the line with the energy available within the limits specified in T 02.02, Vehicle Design Requirements, Performance. In the event that all available energy cannot be accepted, the excess energy shall be diverted to the rheostatic braking resistors. The upper voltage limit to disable regeneration shall be configurable through the use of the laptop portable test unit (PTU). The control shall be such that regenerated current does not oscillate when switching occurs between rheostatic and regenerative braking.

10.07.03. Rheostatic

A. Rheostatic braking shall be provided to supplement the regenerative braking in the event the line is non-receptive or regeneration has been bypassed. Rheostatic braking shall be designed for continuous operation without consideration given to the receptivity of the line. The rheostatic braking shall be sized for continuous operation throughout the entire system without interruption under all conditions specified in T 02.02, Vehicle Design Requirements, Performance, assuming a completely non-receptive line.

10.07.04. Friction Brake Control Unit Interface

A. The propulsion/dynamic braking and friction braking systems shall exchange braking control and status information for slide control, brake blending, and other performance related functions in accordance with a Contractor supplied interface requirements document. The proposed physical interface between the propulsion and friction brake systems shall be direct or proven network link and shall include all necessary inputs and outputs or feedback elements required to accomplish continuous control of braking on a per truck basis. The friction brake control unit shall have the ability to operate independently from the propulsion/dynamic brake control system.

B. The Contractor shall submit the friction brake interface document to the Authority for review and approval. [CDRL 10-09]

10.08: CONTROL

10.08.01. General

A. Propulsion control logic power supplies shall be powered from the Low Voltage Distribution Network.

B. The propulsion control logic shall perform all of the control and fault monitoring related to the inverter operation and vehicle control. The propulsion control logic shall be microprocessor based and shall be of a 32 bit or greater architecture. The microprocessor based propulsion system shall provide continuous control and monitoring of all parameters necessary to perform reliable, safe operation.

C. Not used.

D. The propulsion control logic shall have interfaces with the Digital Network in accordance with T 24.03, Trainlines and Networks.

E. Not used.

F. All control logic inputs and outputs shall be isolated to 1500 VDC.

G. The propulsion control hardware circuits and related software shall respond fast enough to detect and remedy all erroneous or potentially damaging conditions.

H. If an emergency train line request to remove power is received, the propulsion system shall react in a fail safe manner to immediately disable the power to the gate drivers for the IGBTs and open the line contactor.

10.08.02. Load Compensation

A. During vehicle acceleration and braking operations, the propulsion control shall take into consideration the load weight to meet the performance requirements stated in T 02.02, Vehicle Design Requirements, Performance. The load weigh compensation system shall be based on air spring pressure.

B. The load weigh calculation method shall prevent transient changes in air spring pressure or height due to carbody motion from causing instantaneous or oscillating changes in tractive or braking effort.

10.08.03. Roll Back Prevention

A. The Propulsion System shall act in coordination with the Friction Brake System to implement the rollback protection feature. Refer to T 12.03, Friction Brakes & Pneumatic Systems, Integration with Propulsion System.

10.08.04. Spin/Slide Control Capability

A. Each propulsion control logic unit shall detect both synchronous and asynchronous wheel slips, and correct spins by modulating propulsion control.

B. Spin and slide control shall function properly with the maximum allowed variation in wheel diameter between trucks.

C. If a spin occurs during acceleration, power shall be reduced until the spin is corrected. Power shall be reapplied automatically under jerk-limited control.

D. The efficiency of the wheel spin-slide system shall be at least 65 percent in acceleration and 85 percent in braking over the entire speed range. Delay times in response to commands and signals to and from other systems shall be included as part of the efficiency of the system. The spin and slide efficiency shall be defined as the ratio of the actual accelerating or braking rate to the theoretical accelerating or braking rate. The theoretical rate is that which is obtained by continuously utilizing the available track adhesion. Efficiency shall be calculated over the slip-affected portions of operation only.

E. The propulsion shall coordinate with the friction brake system for slide correction. The propulsion system shall react first to correct slides, but if it is unable to correct slides within a preset time, the friction brake system shall take over. For further details refer to the slide control sub section of T 12.03, Friction Brakes & Pneumatic Systems, Integration with the Propulsion System.

10.08.05. Snow Brakes

A. Propulsion system shall compensate tractive and braking effort requests to account for snow brake application as described in T 12, Friction Brakes and Pneumatic System.

10.09: COMMANDS AND TRAIN-LINES

10.09.01. General

A. The propulsion system shall respond to mode selection, directional and rate train lined commands defined in T 24.07, Trainlines and Networks, Coupling, Propulsion Controls and Discrete Trainlines. Propulsion trainlines shall be based upon the position of the Master Controller handle and switches defined in T 05, Operator's Cab, and on the modifications to trainline requests made by the ATP/ASR unit defined in T 15, ATP & ASR.

10.09.02. Jerk Rates and Mode Selection

A. The propulsion system mode change dead times for transitions from propulsion-to-coast, coast-to-brake, brake-to-coast trainline requests shall not exceed the limits specified in T 02.02, Vehicle Design Requirements, Performance. Jerk rates shall be as defined in T 02.02, Performance.

10.10: INTERLOCKS AND BYPASS SWITCHES

10.10.01. Cutout/Bypass Switches

A. A cutout switch shall be provided in the cab to cut out regenerative braking on a train basis.

B. Cutout switches shall be provided in the cab of the Cab Car to cut out propulsion on a per truck basis for each car in the Married Pair.

10.10.02. Interlocks

A. The propulsion and braking trainline shall be interlocked with the door closed status trainline to prevent release of brakes and development of positive tractive effort with any side door open.

B. Propulsion trainlines shall be interlocked with the All Brakes Released Trainline as described in T 24.05, Trainlines and Networks, Coupling, Propulsion Controls and Discrete Trainlines.

C. Traction power shall be disabled when emergency brake application is requested or when the emergency brake pipe pressure drops below 80 psig.

D. The propulsion control logic shall compare vehicle direction with train line direction commands. A failure of the train direction to correspond with the direction commands shall result in no propulsion tractive effort.

10.11: DIAGNOSTICS AND SELF CHECKS AND FAULT LOGGING

10.11.01. General

A. The propulsion system shall provide event, fault and snap shot data to the Vehicle Monitoring Unit over the MTCN per the requirements stated in T 16, Vehicle Monitoring System.

B. The propulsion system diagnostics and fault recording shall be in sufficient detail to allow maintenance personnel to quickly isolate the cause of the fault to the line replaceable unit (LRU).

10.11.02. Fault Log

A. The propulsion system shall maintain a first -in-first out fault log with memory capacity as described in T 16.06, Vehicle Monitoring System, SubSystem Integration.

B. All fault information shall be stored in non-volatile memory.

C. Fault information shall be uploaded to the Vehicle Monitoring Unit (VMU) per T 16, Vehicle Monitoring System.

10.11.03. Self Test

A. The Propulsion System shall perform a self-test of the control logic each time the vehicle is powered up.

10.11.04. Portable Test Unit Interface

A. The propulsion system shall be PTU accessible through an industrial D coded M12 connector.

B. If the inverter control unit is physically separate from the propulsion logic, it shall be provided with the same PTU access interface.

C. Software shall be provided on the PTU to allow reading of fault logs, exercise of diagnostic routines, configuration changes and software upgrades.

1. Software changes and configuration changes to the propulsion logic or inverter control shall be permitted only through the PTU access port and be protected by password.

10.11.05. Wheel Wear Adjustment

A. The adjustment for wheel wear shall be implemented using the PTU. The PTU shall be able to make adjustment in increments of less than 1/4 inch (6.4 mm) over the range from new to fully worn wheels.

10.12: NO-MOTION SYSTEM DESCRIPTION AND CONFIGURATION

10.12.01. General

A. The Contractor shall provide a microprocessor based No-Motion system.

B. No-Motion detection status shall be provided to other vehicle systems.

C. The No-Motion detection system shall monitor multiple speed sensors and shall interface safely with other vehicle systems. No-Motion may not be combined with ATP system. The No Motion system shall provide redundancy such that failure of one speed sensor or No Motion system shall not disable No Motion detection for the train or Married Pair. The system, including any bypass circuitry, shall comply with the requirements for Category I hazards as described in MIL-STD-882C and in T 02.06 of this specification. The Contractor shall submit a functional description of the No-Motion system to the Authority for review and approval. [CDRL 10-10]

D. The Contractor shall provide No-Motion systems that can reliably detect all vehicles speeds down to 1 mph (1.6 km/hr) or less. The No-Motion relay shall be de-energized when the vehicle speed is above 1 mph (1.6 km/hr). Hysteresis control with respect to the 1 mph speed may be provided.

E. The No-Motion circuit shall be fail safe such that, in the event of failure, an "in-motion" or de-energized No-Motion Relay condition results.

F. The No-Motion Relay shall provide interlocks to the door control, coupler control and emergency brake pipe charging circuits through non-welding normally open contacts.

G. Sealed bypass switches shall be provided in the cab to bypass the No-Motion Relay for each car in the Married Pair. Activation of the No-Motion Bypass Switch shall cause the Door Summary Indicator Light on the side of the car to flash. Activation of the No-Motion Bypass switch shall be indicated as an alarm on the Vehicle Monitoring Display. Activation of the No-Motion Bypass Switch for either car of a Married Pair shall illuminate an LED indicator on the cab console and the hostler panel.

10.13: PERFORMANCE

10.13.01. Performance Calculations at Various Line Voltages

A. The Contractor or his sub-supplier shall prepare detailed performance calculations and curves to demonstrate compliance with the performance requirements in T 02.02, Vehicle Design Requirements, Performance. Curves and calculation results shall be provided on electronic media. The document shall include the following information and shall be submitted to the Authority for review and approval. [CDRL 10-11]

1. The Contractor shall provide vehicle acceleration and tractive effort vs. speed curves for various line voltages based on the requirements of T 02, Vehicle Design Requirements. The curves shall be provided for the weights and line voltages listed below.

Line Voltage	Weight
Nominal line voltage	AW0
Maximum line voltage	AW0
Nominal line voltage	AW2
Maximum line voltage	AW2
Nominal line voltage	AW3
Maximum line voltage	AW3

10.13.02. Electric Brake Efficiency Calculations

A. The Contractor shall provide calculations showing regeneration return as a percentage of kinetic energy for a stop from 50 mph (80.5 km/hr), assuming 100 percent line receptivity. [CDRL 10-12]

10.13.03. Equipment Thermal Capacities

A. The Contractor shall provide simulated performance run data showing speed, time, distance, and total train line current draw per the duty cycle normal continuous operation requirements in T 02.02 Vehicle Design Requirements, Performance.

B. The Contractor shall perform a thermal analysis of the power circuits and motor winding temperature rises for the worst-case continuous and towing duty cycles described in T 02.02, Vehicle Design Requirements, Performance. The analysis shall include the maximum ambient temperature and the worst case wheel diameter difference allowed between axles powered from the same inverter. [CDRL 10-13]

10.13.04. Tow Mode

A. The Contractor shall provide simulated towing performance run data showing speed and distance per the requirements stated in towing duty cycle section T 02.02, Vehicle Design Requirements, Performance. [CDRL 10-14]

10.13.05. Efficiency

A. The propulsion system shall meet the power efficiency requirements of T 02.02, Vehicle Design Requirements, Performance.

10.13.06. Emergency Propulsion Shut Down Time

A. Traction power shall be removed within 100 milliseconds by removing power from the IGBT gate drivers when emergency brake application is requested. The Line Contactors shall also be commanded to open.

10.13.07. Slide Control Performance

A. Refer to T 12.03.04, Friction Brakes & Pneumatic System, Slide Correction System and Coordination between Propulsion and Friction Brakes.

10.14: QUALIFICATION TESTING

10.14.01. Environmental Conditions for Testing

A. The environmental conditions described in T 02, Vehicle Design Requirements, shall take precedence over the requirements any standard where the conditions specified of T 02 are more severe.

10.14.02. Traction Motor Insulation Impregnation

A. The Contractor shall manufacture sample sections of the stator and winding assemblies to submit to the Authority for verification of the VPI process. These sample stator assemblies shall undergo the VPI process at the same time as the production stators go through the process. The Contractor shall perform a VPI verification to ensure the stator assemblies are free from voids and to verify that bonding is acceptable. This VPI verification shall be conducted with the first two stators. If the Authority determines that voids are present, then the process shall be modified until corrected and the Contractor shall continue to supply additional samples for review. This process shall continue until the VPI process is corrected. The Contractor shall submit samples to the Authority for review and approval. [CDRL 10-15]

10.14.03. Traction Motor Qualification Testing

A. The first two motors produced, shall be tested under an IEC 60349-2 qualification test, by the manufacturer. In addition any qualification tests required by IEEE STD 11-2000 and not included in the IEC 60349-2 list of tests shall be performed by the manufacturer and submitted to the Authority for review and approval. [CDRL 10-16]

10.14.04. Brake Resistor Qualification Tests

A. The first brake resistor shall be qualification tested per IEC 60077 and IEC 60322. In addition any qualification tests required by IEEE STD 16-2004 and not included in the lists per IEC 60077 or IEC 60322 shall be performed. The first brake resistor shall also be tested as part of the propulsion system laboratory test and results submitted to the Authority for review and acceptance. [CDRL 10-17]

10.14.05. Filter Inductor Qualification Tests

A. The first filter inductor shall be qualification tested per IEC 60077, IEC 60310, IEEE STD 11-2000 and/or IEEE STD 16-2004. Each filter inductor shall also be tested as part of the propulsion system laboratory test and results submitted to the Authority for review and approval. [CDRL 10-18]

10.14.06. Gear Unit Qualification Test

A. The Contractor shall qualify the gear unit for the application. The gear unit shall be mounted in a fixture and arranged to deliver the maximum revenue service torque, continuously, for a period of 24 hours. Test shall include several changes in rotation direction.

B. Testing shall be performed with temperature sensors monitoring gear oil temperature. Oil temperature shall not exceed the gear unit supplier's recommendation for maximum temperature. Noise levels shall be measured and ensured to conform to the overall vehicle limits of T 02, Vehicle Design Requirements. Oil samples shall be tested in an independent lab for evidence of excessive gear wear.

C. The Contractor may request a waiver from the test if the identical gear unit can be proven to have been qualified on a more demanding environment.

10.14.07. Other Components

A. Qualification testing shall be performed per IEEE STD 16-2004 on other major components of the Propulsion System, including, but not limited to, the items listed below. If the Contractor can provide previous test results for the exact same equipment used in a similar application that documents a successful test within the last 5 years, the Contractor may submit these test results to the Authority for review and approval in lieu of conducting tests. [CDRL 10-19]

Rail Gap/ Dead Rail Detector
High Speed Circuit Breaker
Line Contactor
Charging Contactor
Ground Brushes
Speed Sensors

10.14.08. Systems Laboratory Test

A. A combined systems laboratory test shall be conducted on one complete set of propulsion equipment, including the motors, brake resistor(s), power conditioning equipment, inverters, protection devices, logic and controls. To the extent possible cabling and the layout of components shall duplicate the on-car layout. A dynamometer shall be used for this test which simulates vehicle inertia by various methods. The physical layout of car components and cabling shall simulate actual vehicle conditions to the maximum extent possible.

B. The Laboratory test shall simulate the duty cycles and equivalent route profile specified in T 02.02, Vehicle Design Requirements, Performance. The tests shall demonstrate that the propulsion equipment functions properly and meets all performance requirements stated within T 02, Vehicle Design Requirements and in T 10.13 Performance.

C. During the duty cycle tests the inverter IGBT's shall not exceed the limits described in T 10.04.01. Traction Motor Insulation hot spots shall not exceed the limits described in T 10.05.01

D. The Contractor shall simulate all faults listed in T 10.03.01 and verify that the propulsion system detects the faults and reacts as described in CDRL 10-02.

E. The Contractor shall submit test procedures and a list of signals to be measured and recorded to the Authority for review and approval. [CDRL 10-20]

F. This set of propulsion equipment shall also be tested for electromagnetic emissions, conductive and inductive.

1. Conductive and inductive emissions shall be recorded under high, nominal and low line voltage, power and braking levels, transitions, and mixtures of rheostatic and regenerative braking to determine the worst case conductive emissions. Conductive measurements shall be made primarily with a single inverter active.

2. The values of the filter elements and the Systems Laboratory power supply impedance shall be measured and recorded so that the test results can be compared to worst case filter element and field conditions.

   a. Line inductor inductance values shall be measured at various load levels up to maximum line current.

3. To the extent possible in the Systems Laboratory, inductive emissions of the motors and brake resistors, cabling and traction container shall be measured at various power and braking levels.

4. The version number of the inverter and propulsion logic software shall be recorded for reference during field testing.

G. The laboratory tests shall be witnessed by an Authority representative and test reports shall be submitted to the Authority for review and approval. [CDRL 10-21]

10.14.09. Water Tightness Test

A. All enclosures and components, required to be watertight, shall be tested by the Contractor to demonstrate compliance per the requirements stated in T 20.05, Testing & Validation, Qualification Tests.

10.14.10. Integration Testing

A. The Contractor shall comply with the Software Integration Testing required by T 17, Software Systems.

B. The Contractor shall perform the Network and Vehicle Monitoring System Integration Testing required in T24, Trainlines & Networks and T 16 Vehicle Monitoring System.

C. The Contractor shall also perform tests to specifically validate the Friction Brake

Control Unit Interface Document described in T 10.07.04.

10.15: RELIABILITY

10.15.01. Mean Distance Between Component Failures

A. Overall propulsion system reliability, operating in the Red Line and Orange Line environment shall be not less than 120,000 miles (193,121 km) Mean Distance Between Component Failures.

10.15.02. Gear box

A. Motor and Gear box bearings shall be designed for 1,000,000 mile (1,609,500 km) life with 360,000 miles (579,500 km) before requiring service beyond lubrication and oil changes.

10.15.03. Inverter

A. Inverters shall be designed for not less than a 30 year life with a 15 year or greater life for filter capacitors.

10.15.04. Motor

A. Traction motor overhaul intervals shall be a minimum of 10 years.

10.16: MAINTAINABILITY

10.16.01. General

A. The Contractor shall provide an inverter design that permits quick installation and removal as well as easy access to internal mounted devices. Terminals and terminal blocks shall be protected from weather and the operating environment and shall be clearly marked for positive identification.

B. Each Contractor provided traction inverter shall be compact and provide high reliability with a low mean time for replacement.

C. The Contractor shall comply with the maintainability design requirements of T 02.04, Vehicle Design Requirements, Maintainability.

D. The Contractor shall meet the requirements of the Maintainability Demonstration and Pilot Train Maintainability Demonstration described in T 02.04, Vehicle Design Requirements, Maintainability.

10.16.02. Gear Lubrication

A. The gear case shall be provided with a means of measuring oil level. Gear unit lubrication shall be accessible without requiring de-trucking.

10.17: SAFETY

10.17.01. Straps and Hangers

A. The motor shall be provided with safety straps, tabs, or hangers to prevent the motor from falling on the track bed in the event of failure of the primary motor mounts.

10.17.02. Safety Labels

A. All inverter covers containing high voltage capacitors shall be labeled both inside and outside with decals warning of danger from charged capacitors.

10.17.03. Safety Discharge

A. The Contractor shall provide a method ensuring discharge of filter capacitors to 50 volts within 5 minutes in the event the brake chopper fails.

10.17.04. Trainline Conflict

A. A Conflict trainline commands for power and brake lasting greater than an approved length of time shall at minimum inhibit propulsion. .

10.18: FAILURE MODE, EFFECTS, AND CRITICALITY ANALYSIS (FMECA)

10.18.01. Rail Gap Sensing

A. The Contractor shall perform a FMECA on the Rail Gap detection system. [CDRL 10-22]

10.18.02. No-Motion

A. The Contractor shall perform a FMECA on the No-Motion detection system. [CDRL 10-23]

10.18.03. Emissions

A. The Contractor shall perform a FMECA showing compliance with emission limits. [CDRL 10-24]

10.18.04. Emergency Inverter Shutdown

A. The Contractor shall perform a FMECA on the system for emergency shutdown of the inverter. [CDRL 10-25]

10.19: COMPATIBILITY

10.19.01. Interchangeability

A. All major components and minor propulsion system components shall be interchangeable between Red Line and Orange Line vehicles within the requirements of T 02.01 Vehicle Design Requirements, General.

10.19.02. Performance

A. Differences in traction effort, braking effort, and jerk rate requirements between the Red Line and Orange Line shall be a matter of software configuration. Through an ID plug/wiring or other approved method, the equipment shall recognize which vehicle it is operating, and apply the appropriate software configuration automatically.

10.20: CDRL ITEMS REFERENCED

CDRL 10-01, “Propulsion Functional System Description”, (Ref: T 10.01.D)

CDRL 10-02, “Propulsion Protection Concept”, (Ref: T 10.03.01.A)

CDRL 10-03, “Inverter Equipment Layout”, (Ref: T 10.04.01.I)

CDRL 10-04, “Blower Motor”, (Ref: T 10.04.03.A)

CDRL 10-05, “Brake Resistors Type and Design”, (Ref: T 10.04.06.B)

CDRL 10-06, “Speed Sensor Locations”, (Ref: T 10.04.09.A)

CDRL 10-07, “Vacuum Pressure Impregnation (VPI) Process”, (Ref: T 10.05.03.C)

CDRL 10-08, “Traction Motor Cable termination”, (Ref: T 10.05.07.A)

CDRL 10-09, “Friction Brake Interface”, (Ref: T 10.07.04.B)

CDRL 10-10, “No-Motion Functional Description”, (Ref: T 10.12.01.C)

CDRL 10-11, “Performance Calculations and Curves”, (Ref: T 10.13.01.A)

CDRL 10-12, “Electric Brake Efficiency Calculations”, (Ref: T 10.13.02.A)

CDRL 10-13, “Equipment Thermal Capacity Simulations”, (Ref: T 10.13.03.B)

CDRL 10-14, “Tow Mode Performance Simulations”, (Ref: T 10.13.04.A)

CDRL 10-15, “Motor VPI Sample”, (Ref: T 10.14.02.A)

CDRL 10-16, “Traction Motor Qualification Test”, (Ref: T 10.14.03.A)

CDRL 10-17, “Brake Resistor Qualification Test”, (Ref: T 10.14.04.A)

CDRL 10-18, “Filter Inductor Qualification Test”, (Ref: T 10.14.05.A)

CDRL 10-19, “Other Qualification Test”, (Ref: T 10.14.07.A)

CDRL 10-20, “Systems Laboratory Test Procedures”, (Ref: T 10.14.08.E)

CDRL 10-21, "Systems Laboratory Test Results", (Ref: T 10.14.08.G)

CDRL 10-22, “Rail Gap Sensing FMECA”, (Ref: T 10.18.01.A)

CDRL 10-23, “No-Motion System FMECA”, (Ref: T 10.18.02.A)

CDRL 10-24, “Emissions FMECA”, (Ref: T 10.18.03.A)

CDRL 10-25, “Emergency Inverter Shutdown”, (Ref: T 10.18.04.A)

10.21: REFERENCES

10.21.01. Standards Referenced

AGMA 140.01 Gear Material Manual

ANSI/AFBMA Standards Bearing Life

IEEE STD 11-2000 Standard for Rotating Electric Machinery for Rail and Road Vehicles

IEC 60349-2-2002, Electric Traction-Rotating Electrical Machines for Rail and Road Vehicles

IEC 60077-1-1999, Rules for Electric Traction Equipment

IEC 60322, Rules for Ohmic Resistors Used in the Power Circuits of Electronically Powered Vehicles

IEC 61377-1999, Electric Traction – Rolling Stock – Combined Testing of Inverter Fed Alternating Current Motors and Their Control

IEEE 16-2004, Electric Control Apparatus on Rail Vehicles

NEMA MG 1, Motor and Generators

10.21.02. Technical Specification Cross References

T 01, General
T 02, Vehicle Design Requirements
T 05, Operator's Cab
T 09, Power Distribution & Auxiliary Electrical Equipment
T 12, Friction Brakes & Pneumatic System
T 15, ATP & ASR
T 16, Vehicle Monitoring System
T 17, Software Systems
T 18, Materials & Workmanship
T 20, Testing & Validation
T 24, Trainlines & Networks

PART T 11.00
TRUCKS

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11.01: GENERAL

11.01.01. System Description & Configuration

A. The truck design shall be common for both the Red and Orange Line cars, to the maximum extent practical. While an identical truck design may be beneficial to both the Contractor and the Authority, weight limitations and differing suspension characteristics may necessitate a departure from commonality. If a common truck is proposed:

1. The truck structure shall be based on the requirements of the Red Line vehicle.

2. Primary suspension elements shall be tailored to each line.

B. The truck design shall incorporate an FEA optimized structure to ensure weight savings are maximized. The first and all subsequent submissions of the Contractor's Weight Management Plan (T 02, Vehicle Design Requirements) shall address truck design, weight targets and progress towards targets.

C. The Contractor shall propose a truck design which has been successfully proven in service (see definition of service proven equipment in T 01, General) and shall submit a service history of this design for the Authority's review prior to final selection.

D. The truck structure shall be designed for a life which exceeds all other vehicle subsystems without the need for structural repair or overhaul. Design guidelines shall assume continuous service under the most severe environmental and loading conditions defined in T 02, Vehicle Design Requirements. The design qualification speed shall be 70 mph (113 kph).

E. The truck shall be designed to reduce unsprung mass from the existing design, to minimize ground borne vibrations, noise level and wheel/rail wear.

F. The forward most truck shall be designated the No. 1 truck and the trailing truck shall be designated the No. 2 truck.

G. Truck frames (and bolsters, if possible,) shall be interchangeable between car ends, as well as between Cab Cars and Non-Cab Cars. The design shall include the complete complement of bracket mounting provisions to allow swapping of trucks between car ends. Components that differ between car ends shall be limited to parking brake equipment, trip cock, flange lubricators, Automatic Train Protection / Automatic Speed Restriction (ATP/ASR) antenna, leveling valves, piping of leveling valves, sleet scrapers and brake/trip cock hoses. No welding, drilling, tapping, riveting or cutting modifications shall be necessary to move a truck from one location or car to another.

H. Wheelset assemblies, journal bearings, wheels, gearboxes, motors, current collectors, and air springs shall be interchangeable, on either end of the truck and between trucks.

I. The following equipment shall be mounted to the front trucks only: flange lubrication system, trip cocks, parking brake, sleet scraper and ATP/ASR antenna.

J. The truck design shall allow for wheel truing on the existing Orange and Red Line wheel truing machines.

11.02: TRUCK FRAME DESIGN

11.02.01. Truck Frame and Bolster

A. The truck frame shall be an inboard bearing, bolstered or bolsterless design of light weight cast or fabricated/welded steel construction. Refer to T 11.08.01, Truck Frame and Bolster Materials, for additional details.

B. The truck frame shall have precise tram marks above each journal bearing location that mark the center of the journal bearing. Tram marks shall also be precisely located on the bottom of each pedestal horn. The difference between the diagonal tram dimensions shall be less than 0.062 inch (1.6 mm). The difference between the longitudinal distances between tram marks on each side shall be less than 0.031 inch (0.8 mm).

C. The trucks shall be designed to accommodate the brake equipment as required by sections 11.05 and T 12, Friction Brakes & Pneumatic System.

D. Not used.

E. The bolster may be used as an air reservoir for the secondary suspension air springs. If so, it shall be designed in accordance with ASME pressure vessel requirements and tested to 1.5 times the maximum main reservoir air pressure.

1. All reservoirs shall employ an easily accessible drain cock, located to allow complete and total drainage on level track.

2. Reservoirs shall be coated internally in accordance with T 12.05.03, Reservoirs and Drain Valves.

F. Truck frames shall be equipped with lifting eyes, or equivalent, suitable for truck lifting with existing Authority equipment.

G. Two jacking pad locations shall be provided on each side of the truck frame, inboard of the axles. Pads shall be located to allow lifting of one wheel at a time. Pads shall be faced with diamond plate or an equivalent, permanent surface treatment. Pads shall be arranged and sized for jacking with existing Authority equipment.

H. Truck weight shall be optimized through iterative FEA analyses described in T 11.09, Structural Performance.

11.02.02. Truck-to-Carbody Connection

A. The truck shall be attached to the carbody with positive mechanical connections that include locking devices that are easily viewable for inspection without removal of equipment. The connections shall be easily accessible and detachable with standard hand tools to permit de-trucking.

B. Refer to T 11.09.01, Static Strength Requirements, for FEA analysis and performance requirements.

11.03: WHEELSET ASSEMBLIES

11.03.01. General Wheelset Requirements

A. Wheels shall be mounted on axles by an Association of American Railroads (AAR) certified facility using procedures in accordance with the AAR Wheel and Axle Manual. A pressure graph shall be recorded for every wheel, journal bearing and gear hub mounted. Acceptable fits shall be obtained. Poor or unacceptable pressing charts shall be cause for repressing or rejection of wheelsets. All pressing charts shall be included in the Car History Book.

B. The location of wheels installed on an axle shall be controlled by a shoulder on the axle, with the journal bearings and wheels pressed together against the axle shoulder.

C. The back-to-back measurement of wheels installed on an axle shall be nominally 53.375 inches (1355.7 mm). Mounted wheels shall have tread run-out of less than 0.005 inch (0.13 mm) Total Indicated Runout (TIR) measured at the taping line when the wheelset is rotated on the journal bearings. Mounted wheels shall have less than 0.015 inch (0.38 mm) TIR, measured back of flange to back of flange, when the wheelset is rotated on the journal bearings.

D. The truck wheelbase shall be 6 feet 10 inches (2.083 m).

11.03.02. Wheels

A. The wheels shall be wrought steel; manufactured, heat treated and shot peened per AAR M-107, Class B. Wheels shall be fully machined by CNC lathe to produce the best possible dynamic balance. The static imbalance of each wheel shall be less than 105 ounce-inches (.74 Nm), and shall be measured for a minimum of 1 in every 10 wheels produced.

B. Wheels shall be free of defects, marks, galls and imperfections. Wheels passing inspection per AAR M-107 shall be permanently stamped with serial number, date of manufacture, manufacturer code, wheel class and tape size.

C. The wheel profile shall be manufactured in accordance with the profile drawing provided by the Authority during design review.

D. The two wheels on an axle shall be matched within one-half tape (0.020 inch, or 0.5 mm on diameter), measured at the taping line. Wheels installed on the same truck shall be matched within 2 tapes (0.080 inch, or 2 mm on diameter). (Note: These are upper limits for new car delivery, not limits of the spin/slide system.

E. The new wheel diameter shall be 28.00 inches (711.2 mm), and the fully worn wheel shall be 26.00 inches (660.4 mm) in diameter, measured at the taping line.

F. A wheel damping device shall be installed on each wheel. The proposed device shall be similar to the Blue Line wheel damper, or alternate design subject to Authority review and approval. [CDRL 11-01]

11.03.03. Axles

A. The axles shall be an inboard journal bearing design, manufactured of forged steel per AAR M-101. Axles shall be Grade F, double normalized and tempered, having a minimum design/fatigue life of 40 years. Alternative standards that provide an equivalent 40 year life may be proposed for Authority consideration.

B. Relief grooves shall be provided at changes in diameter and shall be cold-rolled after finish machining. The Contractor shall submit axle design calculations to demonstrate applicability of the design to the new cars. [CDRL 11-02]

C. Axle shall be tested, inspected and stamped in accordance with AAR M-101.

D. Axles shall be coated with rust-inhibiting coating. Contractors may propose a service proven product for Authority review and acceptance.

E. The axle ends shall have axle centers and any other provisions required for wheel truing on existing Red and Orange Line wheel truing equipment. Axle end caps shall be provided with seals to protect the axle centers while the car is in service.

F. Hollow axles may be proposed as a weight savings and unsprung mass reduction measure. If hollow axles are proposed, the Contractor shall cite service history of the proposed design and provide a thorough technical description for review and consideration by the Authority. Special tools to perform periodic inspections shall be provided to the Authority.

11.03.04. Journal Bearings

A. The journal bearings shall be double row taper roller bearings having an L-10 life in excess of 1,500,000 miles (2,414,016 km), with an application factor considering the worst track conditions of the Authority's Red and Orange Lines, the average wheel size, maximum operating speed and AW3 passenger loading. The Contractor shall submit journal bearing life calculations to demonstrate compliance with all requirements. [CDRL 11-03]

B. The journal bearings shall be No Field Lubrication (NFL) style with a low-friction type Hydrodynamic Labyrinth (HDL) seal, or equivalent. Two independent sources of manufacture for journal bearings shall be provided to the Authority under this contract. The bearing options shall be shown in the parts list as equivalents. The

Contractor shall supply manufacturers' information, bearing model numbers, lead times and prices for Authority review and approval. [CDRL 11-04]

C. The journal bearings shall not require inspection more than once every 300,000 miles (482,803 km).

D. Journal bearings shall be enclosed in housings that are resiliently mounted to the truck frame by the primary suspension. The wheelset shall be readily removable from the truck frame and journal housings using standard hand tools and standard car house methods. Wheelset removal shall not require removal of wheels or journal bearings. Bearings shall not require the use of a retaining bolt, or any other type of point load device that holds the bearing in place.

E. If chevrons are employed in the design, retainers shall be supplied that hold the axles in proper position and alignment when truck frames are lifted.

F. Detection of journal bearing over-temperature shall be provided at all journal bearings. Detection method shall be by a mechanical means, proposed by the Contractor for Authority review and approval. [CDRL 11-05]

11.04: TRACTION EQUIPMENT

11.04.01. Motor, Coupling and Gearbox

A. The Contractor shall provide a highly reliable motor and single reduction gearbox with a flexible coupling connection between the motor and gearbox.

B. Safety brackets shall be provided on the truck frame to engage and support the motor and gearbox in the event of failure of the primary support arrangement.

11.04.02. Ground Brushes, Traction Power Return and Grounding

A. Ground brushes shall be installed on every wheelset in accordance with T 09.03.03, Ground Brushes. Brushes shall be removable and replaceable while the truck is under the car, using standard hand tools.

B. Insulated grounding cables shall be provided between the carbody, truck frame, bolster, motor, gearbox, junction boxes and the ground brushes. Copper or stainless steel ground pads shall be applied to each component for this purpose.

C. Refer to T 09, Power Distribution and Auxiliary Electrical Equipment, for further details and requirements.

11.04.03. Speed Sensors

A. Speed sensors shall be installed on the motor or gear unit and shall be easily accessible for removal and replacement from a pit while the truck is installed under the car. See section T 10.04.09 for additional information.

B. Speed sensors and their mounting interfaces shall be designed such that no mechanical adjustments are required. The sensor with interface bracket shall be mounted to the motor or gearbox using a simple bolted connection and not require any further adjustment.

C. Sensor wiring shall be housed in armored conduit, or equivalent, for protection from ballast and other flying debris.

D. Refer to T 10, Propulsion & Dynamic Braking and T 15, ATP & ASR, for further details and requirements.

11.04.04. Current Collectors

A. Spring loaded third rail current collectors shall be mounted on each side of each truck. The current collector shall be designed for easy removal and replacement.

B. Collectors shall be a break-away design and be similar to those used on the Authority's existing Orange Line vehicles. Spring force and nominal height of collector shall be proposed by Contractor for consideration by the Authority.

C. Collectors shall be mounted on heavy-duty, insulated brackets, similar to those used on the Authority's Blue Line vehicles. Brackets shall be designed to allow discrete, stepped collector height adjustments.

D. The current collector and shoe beam shall be arranged and shielded to prevent flash-over to any other truck mounted components. Particular emphasis shall be taken in shielding secondary suspension air springs and truck mounted hoses.

E. An air-operated sleet scraper shall be mounted on each side of the No. 1 truck, forward of the current collector. The sleet scraper shall be a trainline energized from a push button in the Operator's console. Activation shall engage all sleets scrapers and energize the indicator light on the Operator's console, as described in T 05.03.05, Illuminated Console Indicators, and the Snow Brake / Sleet Scraper exterior indicator light on both sides of all cars, as detailed in T 08.02.04, Exterior Indicators.

F. Special tools for lifting and securing the current collector are specified in T 05 Operator's Cab and T 09.03, High Voltage Collection and Return.

G. Refer to T 09, Power Distribution and Auxiliary Electrical Equipment, for further details and requirements, including current collector fuse arrangement.

11.05: BRAKE EQUIPMENT

11.05.01. Tread Brakes

A. There shall be four tread brakes per truck, two per axle, which shall meet the requirements of T 12, Friction Brakes & Pneumatic System.

B. The tread brakes shall operate pneumatically, with no air-over-hydraulic or any other hydraulic features.

C. Tread brake units shall be designed to prevent brake shoe from traveling off the wheel tread or making contact with the wheel flange or throat.

11.05.02. Parking Brakes

A. Both axles of the No. 1 truck shall include spring-applied, air-released parking brakes. Refer to T 12, Friction Brakes & Pneumatic System, for detailed requirements and qualification testing.

B. A parking brake indicator light shall be provided in the Cab and on the car exterior.

11.05.03. Trip Cocks

A. Two trip cocks shall be mounted on the No. 1 truck of each Cab Car and Non-Cab Car, one on each side. The trip cock mounting bracket shall be designed to provide sufficient vertical adjustment to accommodate for fully worn wheels.

B. The trip cocks shall meet the requirements T 12, Friction Brakes & Pneumatic System.

11.06: TRUCK SUSPENSION

11.06.01. Primary Suspension

A. The primary suspension shall be rubber with inherent damping characteristics or a coil spring/rubber element combination. If coil springs are proposed, the rubber element shall be arranged to allow for visual inspection of the entire surface area of the spring.

B. Rubber suspensions that exhibit creep, shall:

1. Be classified in three categories of stiffness. The overall range of vertical stiffness for all rubber suspension elements shall not exceed 15%.

2. Test results for the stiffness in all three planes shall be provided in advance for comparison, prior to use.

3. Be color-coded according to the stiffness category.

4. Be installed in matched pairs as follows:

   a. On each axle set, rubber suspension elements shall be from only one of the three stiffness categories.

   b. On each truck, rubber suspension elements shall not have stiffness ranges at the upper and lower bounds. (i.e. on a per truck basis, axle sets may have Category 1 and 2 or Category 2 and 3, but not 1 and 3.)

   c. All springs used on a truck must be from the same production lot.

   d. The vehicle Contractor shall adjust for creep no less than 5 days after the springs have supported the vehicle weight. This may be undertaken under assembled AW0 vehicles or on loading fixtures that accurately apply the appropriate wheel load reactions to the truck.

C. It shall be possible to replace the primary suspension without removing the journal bearing or wheel from the axle.

D. The primary suspension shall have a minimum design life of 7 years in service.

11.06.02. Secondary Suspension / Air Spring

A. The secondary suspension shall incorporate air springs with leveling valves to maintain a constant height under varying passenger loading conditions.

B. An auxiliary air spring reservoir shall be provided to achieve a soft air suspension that maximizes the ride quality of the car while minimizing carbody roll.

C. The air springs shall incorporate internal auxiliary bumpers to limit the vertical travel when normal air pressure is not available. Bumpers shall not be contacted at any time and under any operating conditions except for the loss of pressure. Bumpers shall be of sufficient height to maintain clearances required for safe movement and operation.

D. The springs shall be fabricated from natural rubber, or alternate material proposed for Authority acceptance. Springs and bumpers shall have a minimum design life of 7 years of service.

E. A sudden loss of pressure in one air spring shall cause the mating spring to vent.

F. Cut-out cocks shall be provided on the undercar and in the car interior to cut out the air supply to the secondary suspension. All undercar cut-out cocks shall be located on the same side of the car and accessible from the side of the vehicle.

11.06.03. Leveling Valves

A. Leveling valves shall be a service-proven design of metal construction. Any rubber or wearing elements shall be designed to last a minimum of 7 years in service.

B. The trucks shall be arranged to have a three point leveling valve system per car to control height and the side-to-side level. The No. 1 truck (with a single leveling valve) shall supply air spring pressure to a sensor for load weight compensation. Refer to T 12, Friction Brakes & Pneumatic System, for further details and requirements.

C. The leveling valve dead band shall be the minimum range possible, while achieving a reasonable air usage during operation. The dead band shall be no greater than ±1/2 inch (12.7 mm).

D. Leveling valves shall maintain a level car floor. The maximum side-to-side and end-to-end variation shall be no greater than ±1/4 inch (6.4 mm).

E. The leveling valves shall be protected from contamination using in-line filters. In-line filters shall allow cleaning without removal and without disconnection of the air lines.

11.06.04. Truck Stops

A. Lateral bumpers shall be provided to limit the lateral travel of the carbody, but shall not make contact with the carbody during normal operation.

B. Vertical stops shall limit movement of a suspended truck and limit carbody rotation as required by the vehicle clearance envelope. Maximum travel shall be proposed and justified by the Contractor during design review.

C. The truck shall be fitted with rotational stops.

D. All stops shall bear against stainless steel doubler plates. Elastomeric stops shall provide an increasing spring rate as compression increases.

E. All stops shall provide the damping rate necessary to meet the Ride Quality requirements detailed in T 11.10.05, Ride Quality.

F. All truck stops shall have a minimum design life of 7 years in service.

11.06.05. Dampers

A. Vertical and lateral hydraulic shock absorbers shall be provided to dampen the secondary suspension vertical and lateral motion.

B. Dampers shall provide effective/consistent damping for at least 7 years of service.

11.06.06. Height Adjustment

A. The height adjustment feature shall account for 1.25 inches (31.75 mm) radial wheel wear, in increments of 0.25 inch (6.35 mm).

B. The Contractor shall propose a method of manual height adjustment to provide adjustment in 0.25 inch (6.35 mm) increments. The height adjustment device shall provide clear indication of the level of adjustment provided on both sides of the truck. The method of height adjustment shall not require disconnection of any truck-to-carbody connections including center pin, anchor rods, dampers, leveling valves, etc. Loose shims shall not be employed. The Contractor shall submit the height adjustment design for Authority approval. [CDRL 11-06]

11.07: ADDITIONAL TRUCK MOUNTED COMPONENTS

11.07.01. ATP Antenna

A. The No. 1 truck on the Cab Car shall be fitted with a corrosion proof bar that supports two ATP antennas. ATP antennas may also be supported by individual mounting brackets.

B. The bar (or brackets) shall be resiliently mounted to the truck frame and shall be provided with a back-up safety device which shall prevent the bar/brackets from falling from the truck frame in the event of a failure of the primary brackets or mounting hardware.

C. Brackets and ATP coils shall be designed to be frangible, such that neither coil nor bracket could cause a train derailment. Refer to T 15, ATP/ASR, for antenna details and requirements.

11.07.02. Snow Plow

A. Six snow plows (for each line) shall be provided by the Contractor and shipped loose with the first cars.

B. The snow plow shall be designed to fasten in place of the ATP antenna. Threaded inserts or weld nuts shall be provided to facilitate ease of installation.

C. The lower edge of the plow shall be designed to sit 4 inches (100 mm) above top of rail, with wheels ranging is diameter from 28 inches to 25.5 inches. Clearance to carbody, drawbars, undercar equipment, cables and hoses shall be provided with airbags inflated or deflated. Drive screws shall be provided to raise the plow as conditions require. A minimum of 4 inches (100 mm) of upward travel shall be provided.

D. The plow shall be designed to clear up to 12 inches (305 mm) of heavy snow from the track bed. It shall be symmetric about the centerline of the vehicle.

E. Heavy duty brushes shall be installed to clear snow directly below each trip cock.

11.07.03. Not used

11.07.04. Flange Lubrication

A. The Contractor shall propose a solid stick flange lubrication design suitable for sticks no shorter than 10 inches (250 mm) long. The design shall be truck frame mounted and arranged to facilitate inspection, removal and replacement of the lubricators. The design shall be submitted for Authority approval. [CDRL 11-07]

11.07.05. Piping and Hoses

A. The truck air piping shall be stainless steel seamless tubing, using ferrule compression fittings (no rubber seals or threaded pipe). Hex socket drain fittings shall be provided at the lowest points of the piping to allow routine drainage of moisture if necessary. Close nipples and street elbows shall not be used. Alternate piping material, such as ASTM A106 seamless carbon steel pipe, may be proposed for Authority review and acceptance.

B. Piping shall be located or suitably enclosed to avoid damage from ballast. Piping shall be adequately supported to prevent vibration, rubbing and chaffing. Clamps shall be located within 4 inches (100 mm) of every fitting and every bend greater than 45 degrees.

C. Flexible hoses shall be used at connections to tread brakes, trip cocks and truck-to-carbody connections. All fittings where hoses are attached shall be clamped.

D. Flexible hoses shall conform to AAR M-618, with manufacturing dates provided.

11.07.06. Wiring

A. All high-voltage wiring shall be mounted and supported using cleat blocks with rubber or synthetic non-metallic grommets surrounding the cables.

B. All high-voltage wiring connections shall use heavy duty copper bolted lugs with zinc plating or heavy-duty knife connectors.

C. The 3-phase power cables shall connect to the carbody using a single clam-shell style connection utilizing internal wiping contacts.

D. The high-voltage power collector cable and return cable to the ground brushes shall use separate dual bolted lug connections with insulating covers or heavy-duty knife connectors.

E. Refer to T 09, Power Distribution and Auxiliary Electrical Equipment, for further details and requirements.

F. All low-voltage wiring shall be mounted in flexible or rigid water-tight conduit. Pigtail cables shall be provided for all devices mounted on the motor, gearbox or journal housing (e.g. speed sensors). A single heavy duty, metal construction multi-pin connector shall connect all low-voltage wiring to the carbody. The connector shall include a water-tight back-shell to interface with the conduit.

G. Refer to T 15, ATP & ASR, for ATP wiring details and requirements.

H. All cable routing shall allow movement and rotation of the truck and prevent wire chaffing.

11.08: MATERIALS, JOINING & CORROSION PROTECTION

11.08.01. Truck Frame and Bolster Materials

A. The truck frame and bolster shall be constructed of the following materials:

1. For welded frames, bolsters, truck-mounted components or brackets, the material shall be HSLA steel per ASTM A588 or approved equivalent, having inherent corrosion resistance of at least four times that of carbon steel. After welding, the entire frame and bolster shall be stress relief heat treated prior to machining. Contractor shall submit all material details for Authority approval. [CDRL 11-08]

2. For cast frames, bolsters, truck-mounted components or brackets, the material shall be per AAR M-201 Class B, or approved equivalent.

B. If the bolster is used as an air reservoir, it shall be protected against interior corrosion. After all welding, heat treatment and machining, the reservoir interior shall be thoroughly cleaned to remove all contaminants, and coated with a permanent anti-corrosion coating.

C. Closed sections of the truck frame shall be avoided to prevent internal corrosion.

11.08.02. Welding

A. All weld joints of the frame and bolster shall be 100% full penetration welds that conform to AWS D1.1 pre-qualified welds.

B. All welding procedures shall conform to the applicable AWS D1.1 requirements.

C. All welders shall be certified per AWS to perform the specific welds being applied. Certification shall be within the last six months, or within the last year if the welder has been performing the same welds regularly over the past year. The Contractor shall submit welder certifications to the Authority. See T 19, Quality Assurance, for further details.

D. See T 18.16, Welding, for additional requirements.

11.08.03. Fastening

A. All bolts, nuts, screws, pins and other types of fasteners used on the truck shall be metric, in accordance with T 01, General. Hardware property class 8.8 shall be standard. Grade 10.9 fasteners may be proposed for consideration by the Authority on a case by case basis.

   1. All property class 8.8 fasteners shall be zinc plated per ASTM B633, SC3 thickness, with dichromate conversion coating.

   2. Property class 10.9 fasteners shall be coated with mechanically deposited zinc in accordance with ASTM B695-00, Standard Specification for Coatings of Zinc Mechanically Deposited on Iron and Steel.

   3. Refer to T 18, Materials & Workmanship, for detailed requirements.

B. Torque requirements shall be established for all critical fasteners.

C. Locking mechanisms shall be employed on all fasteners. Locking mechanisms shall be proposed by Contractor for Authority consideration during design review.

11.08.04. Corrosion protection

A. All components used in the assembly of the trucks shall be sufficiently protected from corrosion to meet the truck life requirement of this section.

B. Trucks and truck mounted equipment shall be primed and painted in accordance with T 18, Materials & Workmanship.

C. Surfaces and truck mounted components that are not protected with primer and paint shall be treated with a corrosion inhibitor, such as Tectyl 506, or approved equivalent.

11.09: STRUCTURAL PERFORMANCE

A. Fulfillment of these requirements shall be calculated through FEA analysis [CDRL 11-09] and/or proven through qualification testing. Refer to T 11.15, Qualification Testing, for test requirements.

B. Testing, instrumentation and pass/fail criteria shall be in accordance with T 03.05.03, Carbody Compression Test. A minimum of 100 strain gages shall be used for the Truck tests.

11.09.01. Static Strength Requirements

A. For each of the load cases listed in the tables below, application of the loads shall not result in stresses in excess of 50% of yield.

Description	**Requirement**
Vertical Load	55% of AW3 loading less weight of truck.
Lateral Load	±15% of the vertical load.
Longitudinal Load	±15% of the vertical load.
Tread Braking Loads	Maximum emergency brake force at AW3.
Motor Braking Loads	Maximum braking torque at AW3 or maximum motor torque (FEA shall be utilized to determine worst case).
Truck Frame-Mounted Equipment	30 g shock loads in any direction.

Table 11-1 Truck Strength Requirements

Description	**Requirement**
Vertical Load	Double the complete truck weight, supported by the 4 lifting points.

Table 11-2 Truck Lifting

11.09.02. Truck-to-Carbody Strength Requirements

A. For the load cases shown below, application of the loads listed shall not result in truck detachment from carbody. Alternate approaches to demonstrate compliance to this requirement may be proposed by the Contractor for Authority review and acceptance.

Description	**Requirement**
Vertical Load	30,000 lbs (133 kN)
Horizontal load	150,000 lbs (667kN) applied in any direction

Table 11-3 Truck-To-Carbody Connection Strength Requirements

11.09.03. Fatigue Strength Requirements

A. The fatigue allowable stress shall not exceed the requirements of AWS D1.1, Allowable Stress Range for Cyclically Applied Load in Non-Tubular Connections for 6 million cycles. Fulfillment of all requirements shown below shall be calculated through FEA [CDRL 11-10] analysis. If a new, unproven in service truck design is proposed for use on the project, these requirements shall be proven through testing.

Description	**Requirement**	**No. of Cycles**
Vertical Load	50% of AW0 loading less weight of truck, cycled to 50% of AW3 loading, less weight of truck.	2 million
Lateral Load	15% of the maximum vertical load, cycling between left and right directions.	2 million
Longitudinal Load	15% of the maximum vertical load, cycling between forward and reverse directions.	2 million
Tread Braking Loads	Maximum service brake force at AW3.	2 million
Motor Braking Loads	Maximum braking torque at AW3 or maximum motor torque (FEA shall be utilized to determine worst case).	2 million
Equipment Bracket Loads	±2g of the equipment weight in the vertical, lateral and longitudinal directions in any combination providing the maximum fatigue stress.	2 million

Table 11-4 Truck Fatigue Requirements

11.09.04. Allowable Stresses

A. The Contractor shall submit allowable stresses for static loads based on the strength of the materials and fatigue stress ranges based on AWS D1.1 for 10 million cycles. [CDRL 11-11]

11.09.05. Shock and Vibration

A. All truck frame mounted equipment shall be designed to withstand the shock and vibration requirements found in section T 2.02, Vehicle Design

1. Not used

2. Not used

B. Not used

1. Not used

2. Not used

C. The Contractor shall submit FEA models and calculations to demonstrate compliance to shock and vibration requirements and to demonstrate weight optimization of truck frame design. [CDRL 11-12]

11.10: SAFETY AND DYNAMIC PERFORMANCE

11.10.01. Safety Against Derailment

A. In negotiation of any part of the Red Line or Orange Line system, whether curve or tangent track, with any track irregularity measured (with 10% worse condition allowance), the ratio of lateral force (L) to vertical force (V) on any wheel should not exceed the ratio given by the following (with a coefficient of friction of 0.5):

$$L/V = \frac{\tan\delta - \mu}{1 + \mu \tan\delta} \leq 1$$

1. Where δ = wheel/rail contact angle and μ = coefficient of friction between the wheel and rail of 0.5.

2. This shall be demonstrated by analysis that includes the evaluation of:

   a. New and worn wheels, resulting in the maximum Effective Conicity.

   b. The worn wheel profile shall be any profile not condemnable by current Authority practice.

   c. Variations in suspension stiffness that reflects the anticipated range that would be used in practice.

   d. Variations in damper characteristics that reflect the reduction in damping throughout the 7 year damper life.

B. Truck suspension shall be designed and tested to ensure rollover protection is provided. For a vehicle stopped on maximum track superelevation, as defined in T 02, Vehicle Design Requirements, minimum wheel load shall be no less than 60% of the normal static wheel load measured on level track.

C. Under any combination of track conditions, vehicle speed, suspension condition or passenger loading, wheel load shall not drop below 10% of the normal static wheel load measured on level track.

11.10.02. Wheel Load Equalization

A. The truck shall achieve a static wheel load equalization on level track such that all wheel loads are 23%-27% of the total weight of the 4 wheels of the truck.

B. The truck shall allow any one wheel to be raised or lowered 1 inch (25.4 mm) with a maximum load increase or reduction on that or any other wheel of 17.0 percent, as compared to the level, static track load.

C. The wheel shall be raised and lowered to the maximum reserve deflection, as shown in the truck assembly drawing. Under this condition, no wheel load shall increase or decrease more than 95%, as compared to the level, static track load.

11.10.03. High Speed Stability

A. The vehicle shall remain stable at all speeds up to 70 mph (113 kph), considering any load condition, with either inflated or deflated air springs and the worst track conditions.

B. The condition of stability shall be considered as the absence of hunting, such that there shall be no repeated oscillations without significant damping.

C. Truck rotational stiffness shall be proposed by the Contractor for Authority consideration. Rotational stiffness shall limit hunting while preventing excessive wheel flange wear. The Contractor shall provide a method to verify rotational stiffness and recommend an inspection interval.

11.10.04. Clearances

A. The Red and Orange Line vehicles shall remain within their respective dynamic clearance envelopes under the worst conditions of operation, including: any load, inflated or deflated air suspension, carbody and truck tolerances, wheel/rail wear, track tolerances, track perturbations, track alignment, superelevation and wind.

B. The minimum clearance under the truck, under any condition shall be 2.75 inches (69.9 mm), excluding trip cock levers.

C. There shall be a minimum of 1.00 inch (25.4 mm) clearance between the truck and carbody, including all mounted equipment, with deflated air springs, maximum vertical and lateral motion, maximum truck rotation and new or worn wheels.

11.10.05. Ride Quality

A. Ride Quality requirements are detailed in T 02, Vehicle Design Requirements.

11.11: TRUCK, CARBODY & TRACK MODELING

11.11.01. General

A. Computer simulation shall be used to model the truck and carbody characteristics on the Authority's actual track geometry, in order to predict static, quasi-static and dynamic performance as required in this specification.

B. The Contractor shall use a proven rail transit industry simulation program such as NUCARS, Vampire, Simpack or equivalent, to perform the analyses during the truck design stage, prior to any manufacturing.

C. It is the Authority's intent to work in conjunction with the Contractor in a collaborative effort to ensure that the truck/car modeling properly interfaces with the track data and results in realistic simulation of the operational environment.

11.11.02. Track Geometry

A. Initial track geometry parameters shall be based on the track geometry information provided in the appendix to the specification. Within 90 days of Notice to Proceed (NTP), the Contractor shall set up and instrument a geometry car and perform a track geometry test of the entire Red and Orange Line (including yards) to verify and update the data used in the simulations.

B. All track geometry data shall be collected at a sample rate to ensure that at least one sample is recorded every foot (305 mm) in the files used in the modeling analysis. The geometry car shall be operated at a track speed to ensure proper and accurate data collection through all curves and tangent sections of the Red and Orange Lines.

C. The digital information recorded shall be in the form of space-curve data, input into the modeling software and used to update the initial track geometry. The recorded yard track geometry is a critical part of the exercise, as it is not included in the data provided by the Authority. [CDRL 11-13]

D. The track geometry data collected by the Contractor will be combined with historical geometry data provided by the Authority to ensure that all past or present variances in track quality are considered in vehicle modeling. Any new data collected by the Authority during the project shall be incorporated as well.

11.11.03. Input Data Updates

A. Truck and carbody input data shall be updated as the truck/carbody design proceeds. All estimated values shall be replaced by actual values resulting from component tests. Input data shall be reviewed with the Authority as it becomes available.

11.11.04. Analyses Required

A. The following analyses shall be provided:

1. Low speed curving with rail condition, radius, length, amplitude parameters, as approved by the Authority. Cases with new wheel/new rail, new wheel/worn rail and worn wheel/worn rail combinations shall be performed.

2. Report of outputs and corresponding input criteria for the Net Axle Lateral Force (NAL)

3. Wheel Unloading - equalization with raised and lowered wheel conditions

4. Safety Against Derailment - Wheel L/V (resistance to wheel climb)

5. Safety Against Derailment - Truck side L/V (rollover potential)

6. High Speed Stability - performance at 70 mph with any combination of worn wheel, primary or secondary suspension condition and wheel/rail adhesion condition

7. Ride Quality Assessment

8. Rail wear indices, wheel wear indices, and angle of attack of all wheel sets; and analysis of the worst mainline and yard curves and divergent routes of turnouts.

B. A wheel/rail contact analysis shall be performed to analyze the contact between wheel and rail using the specified wheel profile with the Red and Orange Line rail profiles. The contact performance shall be assessed relative to the contact locations riding on tangent rail and during curve negotiation. The conicity and rolling radius difference shall be presented for review. If the performance is not satisfactory, the Contractor shall recommend an alternative wheel profile to improve the performance, while meeting all other dynamic performance requirements.

11.11.05. Model Results

A. If the results of any portion of the analysis demonstrate an inadequate or marginal performance on any criteria, the Contractor shall revise the truck, suspension or car design to eliminate the problem to the satisfaction of the Authority.

B. The model shall be submitted to the Authority within 90 days after Notice to Proceed. The fully configured model shall be delivered to the Authority as part of the Final Design Review. [CDRL 11-14]

11.12: RELIABILITY

A. The two trucks of each car shall achieve a combined minimum MDBCF of 350,000 miles 563,270 km).

B. The Contractor shall provide a breakdown of the MDBCF allocation for each truck to identify the contribution from:

1. Sub-system equipment mounting brackets and fasteners, leveling valves, truck piping, wiring, wheel lubrication system, suspension components and all remaining truck mounted equipment not included in other sections of the specification. [CDRL 11-15]

C. Subsystem equipment that is covered under the MDBCF requirements of other specification sections need not be included in the truck section. These include failures of motors, brake units, speed sensors, power collection and ATP equipment.

11.13: MAINTAINABILITY

A. The truck shall allow unobstructed access to all equipment for periodic maintenance without requiring the removal of any other equipment. This includes: truck-to-carbody connections, height adjustment, brake shoes, current collector fuses and shoes, motor leads, grease fittings, wire and hose connections, oil fill and drain plugs, oil sight glasses, speed sensors, ground brushes, journal temperature indicators and flange lubrication material.

B. The truck shall permit wheel truing on the existing Orange and Red line wheel truing machines without removal of the truck from the car or any truck components, other than axle end caps. End caps shall be removed with standard hand tools.

C. The trucks shall permit lifting, either individually or when suspended from the carbody, using Authority lifting equipment, including fixed and moveable jacks, car hoists, truck hoists and cranes. Lifting of the entire vehicle, including trucks, shall not require the deflation of air springs or disengagement of air spring seats.

D. All wearing elements shall be made from composite or polymer materials that will maintain a constant coefficient of frictional for at least 15 years of service without any lubrication. All wearing elements shall be easily replaceable with a minimum number of fasteners.

E. Scheduled maintenance tasks shall be coordinated such that major component replacements occur during the same maintenance interval.

11.14: COMPATIBILITY

A. The Red and Orange Line trucks shall be designed to achieve as much commonality as feasible, considering the vehicle dimensional differences and weight limitations.

B. The truck-to-carbody interfaces shall be a common design for both the Red and Orange Line carbodies, including all suspension and structural attachments, wiring connections, air system connections, parking brake connections and all truck to carbody clearance requirements.

C. The Red and Orange Line trucks shall incorporate similar or identical subassemblies, wheelsets and components where ever possible. All components that are identical shall have the same manufacturer and part number.

D. No. 1 and No. 2 trucks of Cab Cars and Non-Cab Cars shall be equipped with all mounting provisions required for use in any location within the Married Pair so that trucks may be easily swapped without the need for welding, cutting or drilling.

11.15: QUALIFICATION TESTING

11.15.01. General

A. These tests shall be individually and separately fulfilled by both the Red and Orange Line trucks, unless sufficient commonality exists in truck design and load cases to satisfy both lines. Contractor waiver requests for each test shall be considered by the Authority on a case-by-case basis.

B. The Contractor shall prepare test procedures for all tests listed below for review and approval by the Authority. [CDRL 11-16]

C. All test reports shall be submitted for review and approval by the Authority. [CDRL 11-17]

11.15.02. Static Load Test

A. The Contractor shall perform a static load test to verify that the maximum allowable stresses are not exceeded when the truck is subjected to the static loads per section T

11.09.01. Loads shall be applied, removed and re-applied a second time. Tests shall be performed with incompressible blocks in place of suspension elements.

11.15.03. Truck Frame Quality Testing

A. After completion of the static tests listed above, all critical welds of the tested truck frame shall be radiographically inspected. A list of critical welds shall be produced by the Contractor for the review and approval of the Authority. [CDRL 11-18]

B. Radiographic inspection shall be conducted per ASTM E 94 and ASTM E 142. Radiographs shall be evaluated in accordance with ASTM E 446.

C. If the first frame results in sub-par performance, the second frame will be tested and subsequently inspected in the same manner. This process will continue until a frame fully passes the testing.

D. Testing shall then be completed, but radiographic testing will continue on 10% of the truck frames, chosen at random by the Authority.

E. Once 10 frames have passed these tests, the sampling rate will be reduced to 4% of the truck frames. Any failures shall cause the process to revert to 100% radiographic inspection.

F. 100% of the truck frames shall be tested via Magnetic Particle Inspection (MPI). The Authority may allow a reduction in the 100% requirement with consistently successful results.

G. Alternate approaches to radiographic testing that provide the same or better verification of quality control may be proposed for Authority consideration.

11.15.04. CDRL Items Referenced

CDRL 11-01, “Wheel Damper”, (Ref: T 11.03.02.F)

CDRL 11-02, “Axle Design Calculations”, (Ref: T 11.03.03.B)

CDRL 11-03, “Journal Bearing Life Calculations”, (Ref: T 11.03.04.A)

CDRL 11-04, “Journal Bearing Manufacturers”, (Ref: T 11.03.04.B)

CDRL 11-05, “Hot Box Detection”, (Ref: T 11.03.04.F)

CDRL 11-06, “Height Adjustment Details”, (Ref: T 11.06.06.B)

CDRL 11-07, “Flange Lubrication Details”, (Ref: T 11.07.04.A)

CDRL 11-08, “Truck Materials”, (Ref: T 11.08.01.A.1)

CDRL 11-09, “Static Loads FEA Analysis”, (Ref: T 11.09.A)

CDRL 11-10, “Fatigue Loads FEA Analysis”, (Ref: T 11.09.03.A)

CDRL 11-11, “Allowable Stresses”, (Ref: T 11.09.04.A)

CDRL 11-12, “Shock and Vibration Stress Analyses”, (Ref: T 11.09.05.C)

CDRL 11-13, “Track Geometry”, (Ref: T 11.11.02.C)

CDRL 11-14, “Truck/Carbody Modeling”, (Ref: T 11.11.05.B)

CDRL 11-15, “Reliability Breakdown”, (Ref: T 11.12.B.1)

CDRL 11-16, “Truck Test Procedure Submittal”, (Ref: T 11.15.01.B)

CDRL 11-17, “Truck Test Report Submittal”, (Ref: T 11.15.01.C)

CDRL 11-18, “Truck Frame Critical Welds”, (Ref: T 11.15.03.A)

11.16: REFERENCES

11.16.01. Standards Referenced

AAR M-101, Axles

AAR M-107, Wheels

AAR Wheel and Axle Manual

AAR M-201, Steel Castings

AAR M618, Hoses

ASTM A588, Standard Specification for High-Strength Low-Alloy Structural Steel with 50 ksi Minimum Yield Point to 4 in. Thick

ASTM B633, Standard Specification for Electrodeposited Coatings of Zinc on Iron and Steel

ASTM B695, Standard Specification for Coatings of Zinc Mechanically Deposited on Iron and Steel

ASTM E94, Standard Guide for Radiographic Testing

ASTM E125, Standard Reference Photographs for Magnetic Particle Indications on Ferrous Castings

ASTM E 142, Standard Method for Controlling Quality of Radiographic Testing

ASTM E165, Standard Test Method for Liquid Penetrant Examination

ASTM E390, Standard Reference Radiographs for Steel Fusion Welds

ASTM E446, Standard Reference Radiographs for Steel Castings Up to 2 in. in Thickness

ASTM E662, Test Method for Specific Optical Density of Smoke Generated by Solid Materials

ASTM E709, Standard Guide for Magnetic Particle Examination

AWS D1.1, Structural Welding Code - Steel

AWS D1.3, Structural Welding Code - Sheet Steel

ISO 2631 (0.5 - 80 Hz) Mechanical vibration and shock – Evaluation of Human Exposure to Whole – Body Vibration. Part 1: General Requirements

11.16.02. Technical Specification Cross References

Cross references to other internal specification sections required to fully describe the system discussed in this section as follows:

T 01, General
T 02, Vehicle Design Requirements
T 03, Carbody
T 05, Operator's Cab
T 08, Lighting
T 09, Power Distribution &Auxiliary Electric Equipment
T 10, Propulsion & Dynamic Braking
T 12, Friction Brakes & Pneumatic System
T 14, Interior & Exterior Appointments
T 15, ATP & ASR
T 18, Materials & Workmanship
T 19, Quality Assurance
T 20, Testing & Validation
T 22, Systems Assurance

PART T 12.00
FRICTION BRAKES & PNEUMATIC SYSTEM

Table of Contents

12.01: GENERAL

A. The friction brake system shall be a pneumatically operated, electrically controlled system of a fail-safe design.

B. The friction brake system shall provide variable level service brakes with slide control.

C. The friction brake system shall be of a tread brake design.

D. A fail safe emergency brake design shall be provided.

E. The performance of the friction service and emergency brakes shall meet the requirements of T 02.02, Vehicle Design Requirements, Performance.

F. A functional description of the friction brake and pneumatic systems shall be submitted for Authority review and approval. [CDRL 12-01]

G. Unless approved by the Authority, all parts of the friction brake system with the exception of the air supply shall be provided by the same supplier.

H. The Contractor, with copy to the Authority, shall receive certification from the brake system supplier that the application and method of installation and connection of the system have been reviewed and approved by the brake system supplier. A copy of this certification shall be submitted to the Authority. [CDRL 12-02]

12.02: SYSTEM DESCRIPTION & CONFIGURATION

12.02.01. System Description

A. There shall be two modes of friction brakes application during vehicle operation: service braking and emergency braking.

B. . There shall be no pneumatic trainline for control of the service friction brakes. The service friction brakes application shall be coordinated on a per truck basis with the propulsion system to provide brake blending and slide control. Friction brakes shall provide the part of the service brake effort request that cannot be satisfied by the electric brakes of the propulsion system.

C. The service friction brakes shall normally be used for deceleration only during the dynamic brake system fade out or high speed taper.

D. The application of friction service brakes shall be controlled by a microprocessor based Friction Brake Control Unit (FBCU).

E. Emergency brakes shall be an irreversible fail safe brake application, which occurs on all cars in the train any time the pressure in the Emergency Brake Pipe trainline drops below 80 psig. Propagation of the emergency brake command shall take place both electrically through removal of energy from the emergency brake magnetic valves and pneumatically through loss of Emergency Brake Pipe pressure.

1. Pneumatic propagation is required due to the use of trip stops at yard exits,some terminal locations and work zones. If fail safe electrical detection of trip cock activation can be provided, electrical only propagation may be considered.

F. A snow brake feature shall be provided such that when the operator activates the electrical snow brake train line a light pressure is applied at all tread brakes to prevent the buildup of ice and snow on the wheels and brake shoes.

G. Slide control, when performed by the friction brakes, shall be provided through a modulating slide control magnet valve by the Friction Brake Control Unit. Slide control for blended braking shall be coordinated between the propulsion control and the Friction Brake Control Unit.

H. Tread Brake Units (TBU) shall be provided at all wheels.

I. A spring apply/air release parking brake feature shall be incorporated into the brake system of the number 1 truck of each car.

J. The Contractor shall provide one air compressor per Married Pair. The Contractor shall supply the necessary air dryer, piping, valves, check valves and storage tanks to supply all the compressed air requirements of the brake system and all other pneumatic systems of the vehicle.

12.02.02. Electro-Pneumatic System

A. The service friction brake system shall be electro-pneumatic based controlled through the Friction Brake Control Unit. Propagation of service brake commands shall be entirely by electric trainlines.

B. The FBCU shall be designed to provide separate friction brake control for each truck. The Contractor shall provide one Brake Valve Manifold Unit per truck with all the necessary piping and valves to implement FBCU, Emergency Brake Pipe and Emergency Trainline commands.

C. The Contractor shall provide an Emergency Brake Pipe control unit on each car or at each Brake Valve Manifold Unit.

D. The Contractor shall provide a modulating slide control magnet valve for each truck.

12.02.03. Friction Brake Control Unit.

A. The Friction Brake Control Unit shall be microprocessor controlled. The FBCU shall be separate from, but work in coordination with the propulsion control logic. It shall:

1. Provide separate control of the friction brakes for each truck.

2. Read propulsion and braking control trainlines described in T 24, Trainlines & Networks to determine the requested brake rates.

3. Read directly the signals from the propulsion speed sensors for each axle.

    a. The FBCU shall independently read a speed sensor for each axle.

    b. See T 10, Propulsion & Dynamic Braking, Speed Sensors, for details of mounting and wiring.

4. Read the snow brake trainline described in T 24.05, Trainlines & Networks, Coupling, Propulsion Control and Discrete Trainlines.

5. Communicate directly with the propulsion controls for the associated truck to coordinate friction brake blending and slide control.

6. Control the slide control modulating magnet valve.

7. Read brake cylinder pressure before and after the slide control magnet valve to monitor and control brake cylinder pressure and to detect faults.

8. Control the service brake cylinder pressure on each truck through the valves in the Brake Valve Manifold unit.

9. Provide load weight compensation on the basis of air spring pressure.

B. Pressure sensing shall be implemented through a strain gauge sensing system or other reliable system with no moving parts.

C. The FBCU shall be powered from a separate circuit breaker on the low voltage DC power system.

D. The FBCU shall have network interfaces as described in T 24, Trainlines & Networks.

E. The FBCU shall perform self-monitoring and shall default to a more restrictive state in case of a failure that could result in a hazardous event.

F. The FBCU shall report faults and defined parameters to the Vehicle Monitoring system (VMS) as described in this section and in T 16, Vehicle Monitoring System.

G. The FBCU shall have a local access port for connection to a laptop Portable Test Unit (PTU).

1. The FBCU shall be PTU accessible through an industrial D coded M12 connector.

2. PTU software shall be provided to allow full access to all fault and event logs, to system diagnostics and to allow configuration changes and software upgrades. Software and configuration changes may only be made through the local access port.

12.02.04. Brake Valve Manifold Unit

A. The Brake Valve Manifold Unit (BVMU) shall consist of the pneumatic and electro-pneumatic valves and fittings necessary to control the passage of compressed air to and from the brake cylinders of each truck.

1. The unit shall be pipe bracket mounted and arranged to permit removal of individual operating devices without disturbing any other components. The pipe brackets shall be bolted to the vehicle under frame and shall contain the connections for external pipe work, along with cored and drilled passages to provide the necessary interconnections between the mounted valves and switches.

2. The arrangement shall permit service and repair without special tools or disturbance of adjacent piping. Electric components shall be of ruggedized construction consistent with the operational environment and the required life expectancy.

12.02.05. Emergency Brake Control

A. The brake system shall be designed in a failsafe manner such that a drop in Emergency Brake Pipe pressure below 80 psig or a sudden drop in pressure from any level shall cause an irretrievable application of full Supply Reservoir pressure to the Variable Load Valve. Stable Emergency Pipe pressure above 85 psig shall allow the service brake control valve(s) to control the brake cylinder pressure.

B. The system shall allow the Authority to disable spin/slide control in any or all modes of emergency brake initiation.

12.02.06. Emergency Brake Pipe

A. An Emergency Brake Pipe pneumatic trainline shall be provided.

B. One Emergency Brake Pipe Control Unit consisting of charging and venting valves shall be supplied per car. The charging and venting valves shall include:

1. A pneumatic vent valve which shall respond to Emergency Brake Pipe pressure below 80 psig or to rapid negative changes in Emergency Brake Pipe pressure by venting the Emergency Brake Pipe to atmosphere.

2. An Emergency Magnet Valve (EMV), which shall open upon loss of electrical energy to vent the Emergency Brake Pipe. When activated, the EMV shall close and allow recharging of the Emergency Brake Pipe.

3. Flow limited charging and maintaining valves to charge the Emergency Brake Pipe from the Main Reservoir.

C. The capacity of the charging and maintaining valves shall be limited so that failure of any or all charging valves shall not prevent the initiation or propagation of an emergency brake application by either pneumatic or electric means.

D. The charging and maintaining valves shall maintain the Emergency Brake Pipe pressure at 110 psig.

E. To prevent the accumulation of water, there shall be no water traps in the Emergency Brake Pipe.

F. Charging of the Emergency Brake Pipe may only take place when:

1. The train is at zero speed.

2. The Automatic Train Protection (ATP) module on the controlling car permits it (or is bypassed).

3. The Master Controller or Hostler Panel of the controlling car is in the full service brake position.

G. Emergency Brake Pipe Pressure Switches located in each car shall sense the loss of Emergency Brake Pipe pressure and shall cause a shutdown of the propulsion system and an emergency brake application when the pressure drops below 80 psig.

H. Opening or loss of integrity of the Emergency Trainline shall cause the removal of power to all Emergency Magnet Valves (EMV) beyond the break and evacuation of the Emergency Brake Pipe.

I. Accidental uncoupling between any two cars in the train shall vent the Emergency Brake Pipe.

J. Trip cock activation shall evacuate the Emergency Brake Pipe.

K. Activation of the Operator's Emergency Brake Pushbutton shall open a mechanical valve venting the Emergency Brake Pipe. Also, activation of the Operator's Emergency Brake Pushbutton shall electrically open the Emergency Trainline and disable slide correction. Activation of any Operator's Emergency Pushbutton shall be indicated to the Event Recorder and to the Vehicle Monitoring System, which shall display an alarm on the Vehicle Monitoring Display (VMD).

L. The operation of the Passenger Emergency Stops is described in T 14, Interior & Exterior Appointments. Activation of the Passenger Emergency Stop shall open the Emergency Trainline as described in T 24, Trainlines & Networks and cause venting of the Emergency Brake Pipe and an emergency brake application.

12.02.07. Service Brake Control Valves

A. The Apply and Release magnet valves shall modulate the control air for controlling the brake cylinder pressures in the service brake mode. Alternative methods for controlling brake cylinder pressure in service brake mode, such as a force motor controlled proportional valve, may be proposed for Authority approval.

1. If a force motor is used, the design shall result in an application of brakes with a loss of force motor current.

12.02.08. Load Weight Management and the Variable Load Valve

A. Load weight compensation shall use a strain gauge pressure sensor to measure the air spring pressure. Air Spring pressure reading shall be available to both propulsion and friction brake control. Using the air spring pressures, the FBCU shall calculate the load weight variable proportional to a car weight between AW0 and AW3. The jerk limited trainline brake rate request signal shall be continuously multiplied by the load weight compensation signal to produce the commanded braking effort. The load weight system shall meet the performance requirements of T 02, Vehicle Design Requirements, Performance, including performance under failure modes.

B. A method shall be provided to prevent transient changes in air spring pressure due to carbody motion from causing instantaneous or oscillating changes in braking effort.

C. The Variable Load Valve shall provide a pneumatically controlled, load weight compensated limit of maximum emergency pressure to the brake cylinders. The Variable Load Valve shall be controlled by the air spring pressure. Loss of air spring pressure shall not cause a reduction of brake pressure below the AW0 emergency pressure.

12.02.09. Slide Control Valve

A. A modulating slide control magnet valve shall be provided in the brake cylinder pipe for each truck.

B. The FBCU shall control both the positive and negative electrical energy to the slide control valve.

C. Strain gauge pressure transducers shall be located on the brake cylinder pipe before and after the slide control magnet valve to enable the FBCU to to detect valve failures. Alternate methods of detecting mechanical slide control valve failures may be proposed.

12.02.10. Tread Brake Units (TBU)

A. A compact, pneumatic tread brake unit shall be provided for each wheel. Each unit shall receive air pressure under control of the FBCU and apply braking pressure to the wheel tread through a composition brake shoe.

B. The units shall be mounted to the truck frame in such a manner as to ensure proper location of the brake shoe relative to the wheel at all times and under all operating conditions. This position shall accommodate a maximum diameter new wheel and a maximum thickness new brake shoe and the minimum worn out brake shoe and minimum wheel diameter.

C. The tread brake unit shall have automatic slack adjusters, which shall accommodate a combined radial wear of at least a fully worn wheel, worn suspension and brake shoe wear plus tolerances.

1. The unit shall provide a maximum brake effort with a new or fully worn brake shoe when used with a new or minimum diameter wheel.

2. The unit shall provide for a positive retraction following every brake release command.

3. The brake shoe and brake shoe hanger arm shall retract at all times other than when friction brakes are applied.

4. Lateral forces shall not cause the brake shoe to ride off the tread of the wheel.

5. The positive clearance retraction design features shall assure quick and convenient replacement of brake shoes from the side of the car.

6. The positive clearance adjusting device shall not involve friction elements in contact with surfaces that are used for sealing.

D. It shall be possible to readily and positively distinguish between a brake applied and a released condition at the tread brake unit by visual inspection during a walk-by of the vehicle.

E. Standard lubrication fittings shall be provided at all points requiring periodic lubrication. The fittings shall be fully accessible from the side of the car with the tread brake unit mounted on the truck.

F. The brake shoe face radius shall be sized to match the new wheel with at least 2.00 inches wear available on the shoe. It shall be the responsibility of the Contractor and its subcontractor to achieve the specified brake performance characteristics with the shoe material provided, while minimizing the braking noise.

12.02.11. Trip Cocks

A. There shall be two trip cocks per car, one on each side of the lead truck slightly to front of the center of the lead axle. The trip cocks shall be self-resetting and shall be designed so that the opening of the cock shall cause an evacuation of the Emergency Brake Pipe and an emergency brake application.

B. The trip cock shall remain open until Emergency Brake Pipe pressure is reduced to a low enough pressure to ensure that the emergency vent valve is opened under any operating condition. The trip lever shall be of proper length and shape so that the lever shall positively engage the track-mounted train stop. Details of the trip lever will be provided at design review.

C. The trip cock shall be vertically adjustable in 0.25 inch increments. The adjustment range shall allow for new to fully worn wheels. See T 02.01, Vehicle Design Requirements, General, for maximum and minimum height adjustment.

D. There shall be a cutout for de-activation of the trip cock. The trip cock cutouts shall be provided in the following locations:

1. Undercar, accessible from the side of the car

2. In an enclosure in the cab of the cab car

3. In a locked enclosure in the passenger area of the non-cab car.

E. The trip cock cutouts shall be clearly marked. Activation of any trip cock cutout shall be distinguishable at both the interior and undercar cutout and annunciated on the Vehicle Monitoring Display (VMD). Cutouts activated at the interior or undercar cutout may be reset at either the interior or undercar location.

F. Activation of the trip cock shall be sensed with a limit or proximity switch and reported to the Vehicle Monitoring System for display on the VMD.

12.02.12. Parking Brake

A. A spring applied, air release parking brakes shall be provided on the No. 1 Truck of each car. The parking brake shall apply whenever a direction is not selected from the Master Controller.

B. Parking brake shall have a backup mechanical release which can be operated from locations inside the car as well as outside of the car. The mechanical release shall not require power or pneumatic pressure to operate. Activation of the mechanical release shall be clearly visible from outside the car.

C. Application of normal air pressure to the pneumatic release shall disable the mechanical release and return the parking brake to normal spring apply/air release operation.

D. A means shall be provided for re-applying parking brakes after mechanical release when no air pressure is available from the main reservoir.

E. The parking brake shall have an interlock that prevents the train from developing positive propulsion unless all parking brakes are released.

F. Application of the parking brake either by evacuation of release air or re-application after a mechanical release shall cause the parking brake indicator light on the side of the car to illuminate.

G. The contractor shall submit plans for the Parking Brake and the back up mechanical release and apply mechanisms to the Authority for review and approval. [CDRL 12-03]

12.02.13. Snow Brake

A. When the snow brake/sleet scraper train line is set active, the FBCU shall command a continuous light brake application just sufficient to prevent the buildup of snow or ice between the brake shoes and the wheel and to keep the wheel interface clean and dry. This command shall be active as long as the train line is set active, even when a complete brake release is requested.

B. The friction brake system shall adjust for brake shoe wear during snow brake operation. The duration and frequency of the release of brakes during slack adjustment shall be such that snow and ice do not build up as a result of the adjustment. No release for adjustment shall take place while the train is stopped.

C. The FBCU shall account for snow brake application in calculating the braking effort required to meet the trainline required.

D. The FBCU shall inform the propulsion logic of the application of the snow brakes.

E. When the Master Controller in the controlling cab is keyed off, the snow brake function shall be disabled.

12.02.14. Manual Brake Cutouts and Gauge Port Manifolds

A. Pressure test fittings shall be provided in air lines to gauges and other apparatus, such as pressure switches and pressure transducers, requiring periodic routine calibration. The fittings shall allow for simple and accurate calibration and testing (both static and dynamic) without removing the item being tested from the vehicle. It shall be possible to connect test gauges to the system while the system is fully charged through the use of quick disconnect test fittings. Fittings shall be close coupled to the device which they serve and shall be mounted in an accessible location.

B. Quick disconnect test fittings for the cab pressure gauge lines shall be provided on a manifold behind an easily accessible panel below the Operator’s console. The following test fittings shall be provided at this location:

1. Main Reservoir Pressure
2. No. 1 Truck Brake Cylinder Pressure
3. No. 2 Truck Brake Cylinder Pressure
4. Emergency Brake Pipe Pressure

C. Quick disconnect test fittings shall be provided on a manifold in an enclosure near the Hostler Panel of the Non-Cab Car. The following test fittings shall be provided at this location:

1. Main Reservoir Pressure
2. No. 1 Truck Brake Cylinder Pressure
3. No. 2 Truck Brake Cylinder Pressure
4. Emergency Brake Pipe Pressure

D. The exterior quick disconnect gauge ports shall be located such that pressures may be monitored while inspecting, adjusting or repairing the associated system. Exterior pressure test fittings shall be provided as follows:

1. Brake cylinder pressure, No. 1 Truck, accessible at side of car

2. Brake cylinder pressure, No. 2 Truck, accessible at side of car
3. Emergency Brake Pipe, accessible at side of car
4. Main Reservoir Trainline, accessible at side of car
5. Supply Reservoir No. 1 Truck, accessible at side of car
6. Supply Reservoir No. 2 Truck, accessible at side of car
7. Air spring pressures, No. 1 Truck, accessible at side of car
8. Air spring pressures, No. 2 Truck, accessible at side of car

E. Two manually operated, vented Brake Cutout Valves (BCO), one for each truck, shall be provided in the brake cylinder lines between the Brake Valve Manifold Unit and the tread brake units.

1. The BCOs shall be equipped with limit switches to indicate valve position.
2. Each brake cutout shall be operable from the exterior side the car and from the cab on the Cab Car or from the Hostler Panel area of the Non-Cab Car.
    a. The cutout control in the Hostler Panel area shall be in a locked enclosure.
    b. The cut-in and cut-out positions of the interior control handles shall be visibly, legibly, and indelibly marked according to truck behind the enclosed panel.
3. The exterior BCO cutouts shall be on the same side of the car.
4. The cutout position of the truck BCO shall be sensed and signals supplied to the FBCU and to the VMS to inform the train crew of the Brake Cutout.
5. Activation of any BCO shall be clearly detectable at both the interior and undercar cutouts. Cutouts activated at the interior or undercar cutout may be reset at either the interior or undercar location.
6. The BCO shall be upstream of the truck brake line pressure sensors and gauge/test port line.
7. If brake cylinder pressure exceeds 10 psig with brakes cut out, the VMS shall alert the operator of the failed Brake Cutout.
8. The location of the exterior cutout handle shall be clearly marked on the side of the car with the letters "BCO" and truck identification.

F. Secondary Suspension / Air Spring Cutout Valves shall be provided in enclosures in convenient locations inside each car close to each truck. Exterior Air Spring cutout handles shall be provided and shall be accessible from the same side of the car as the BCO cutouts.

G. All cutout cocks shall be aligned with the handle in line with flow when flow is cut off and perpendicular to the flow when flow is permitted.

H. All cutout cocks, not remotely accessed, shall be self locking in both the open and closed positions.

I. Any cutout cocks that isolate systems that require removal of air prior to servicing shall be vented on the component side.

J. The Contractor shall submit, plans for the location and design of all cutouts and test manifolds, for both Cab and Non-Cab cars, to the Authority for review and approval. The plans shall be submitted prior to Preliminary Design Review. [CDRL 12-04]

12.03: INTEGRATION WITH PROPULSION SYSTEM

12.03.01. Brake Blending

A. The FBCU shall read the propulsion and braking control trainlines as described in T 24.07, Trainlines & Networks. The FBCU shall receive electric braking data as well as electric braking status and brake achieved signals from the propulsion control unit for each truck. The FBCU shall control the Apply and Release valves (or force motor proportional valve) to compensate for the difference in braking effort between the load weight adjusted, jerk limited trainline request and the dynamic braking effort.

B. If the propulsion system fails to update its braking achieved and status data, or is unable to provide dynamic braking, the FBCU shall control the brake valves to provide requested braking effort up to the requirements of T 02, Vehicle Design Requirements.

C. The FBCU shall interpret the trainline commands in a manner such that loss of signal or failure to update shall be interpreted as a request for full service brakes.

D. The jerk rate limit used by the FBCU shall be a software configurable parameter.

E. The details of the interface between propulsion control and the FBCU shall be in accordance with T 10.07.04, Propulsion & Dynamic Braking, Friction Brake Control Interface, and the approved friction brake interface document.

12.03.02. Roll Back Protection

A. The FBCU shall coordinate with the propulsion system to provide roll back protection during start up on grades. The roll back feature shall allow for an AW3 train, with half the motors cut out, to start on a 5% grade without rolling back. If roll back exceeds 25 degrees of wheel rotation, a roll back fault shall be declared and full service brakes shall be applied.

B. Roll back protection shall be enabled when vehicles are controlled from cabs or hostler panels.

C. Failure of the propulsion system to provide power shall not result in a roll back.

12.03.03. All Brakes Released Interlock.

A. The FBCU shall sense the brake cylinder pressure and shall provide an output for each truck to control the All Brakes Released Trainline.

B. Circuitry shall also be provided to detect application of the Parking Brake either mechanically or through removal of pneumatic pressure from the release side of the Parking Brake Unit. Application of the Parking Brake shall disable the All Brakes Released Trainline.

C. The All Brakes Released Trainline shall, in accordance with T 24.07, Trainlines & Networks, inform the propulsion and braking trainline control when all brakes and parking brakes are released. If the All Brakes Released Trainline is not satisfied within a preset delay time after power is requested, a brakes holding fault shall be declared. The controlling Married Pair shall control the trainlines to remove power and re-apply brakes. The delay time shall be set so as not to interfere with roll back protection. The minimum pressure for declaring brakes are not released shall be set high enough so as not to conflict with the snow brake or any inshot function.

D. When the BCO is in the cut out position, the contacts for control of the All Brakes Released Trainline shall be bypassed for that truck.

12.03.04. Slide Correction System and Coordination between Propulsion and Friction Brakes

A. Slide correction shall be provided as an integral part of the propulsion and friction brake control systems.

B. Slide control shall operate on a per truck basis.

C. The propulsion and friction brake systems shall independently read the propulsion speed sensors. The Contractor shall use speed sensors from all axles within a car to determine a spin/slide condition. If the propulsion system is not operational, the friction brake system alone shall perform slide correction. The slide correction control shall function properly with maximum allowable wheel diameter differences between trucks.

D. Correction control shall be provided independent of the type of slide, random or synchronous, at all operational speeds, under all adhesion conditions.

E. Slide control algorithms shall be designed to optimally meet the two goals of minimizing wheel flats and maintaining a minimum average braking rate of at least 1.6 mphps. This may include allowing some intermittent controlled sliding in low adhesion conditions to clean the rail and change the available adhesion.

F. If a slide occurs during braking, braking effort shall be reduced on the affected truck until the slide is corrected. The propulsion control will then try to correct the slide. After the slide has been corrected, the appropriate braking effort shall be reapplied without exceeding the jerk limit for the vehicle.

G. Friction brake slide control shall be through the modulating slide control valve. Control of the valve shall be through control of both positive and negative energy to the slide control valve.

H. The FBCU shall detect modulating valves stuck in the release position. Failure of the modulating valve shall cause the friction brake system to disable slide control on that truck and shall inform the Vehicle Monitoring System of the failure so that the operator can be warned.

I. Not used.

J. Slide control shall be active during service brake application.

K. Both the propulsion and friction brake control units shall monitor the speed sensors for all four axles (or motors) and shall disable slide sensing from any speed sensor for which a speed sensor failure is detected.

L. The slide control system shall detect the onset of both asynchronous and synchronous slides by sensing different axle speeds and different or inconsistent rates of change of axle speeds.

M. Slide control shall be hardware disabled during an emergency brake application initiated from the Emergency Mushroom Switch, the trip cock or the ATP unit. Software disabling is not acceptable.

N. Provisions shall be made to allow the Authority to install jumpers to bypass the hardware disabling of slide control during emergency braking. The Authority shall use tests of the slide control system and the FMECA required in this section to determine whether to allow slide control under any or all emergency brake conditions.

12.04: DIAGNOSTICS AND FAULT LOGGING

12.04.01. General

A. The FBCU shall monitor and log data relating to system control signals and fault indications. The monitoring system shall measure and record all relevant data required to accurately diagnose the brake system for faults and track the response of the brake system at all times in accordance with the Fault Management Plan of T 16.07, Vehicle Monitoring System, Fault Management Description.

12.04.02. Self-Tests

A. The FBCU shall provide the following self-test and diagnostic features:

1. Power-up and routine fit for service self-test and fault indication.

2. Not used.

3. Operational monitoring and fault indication.

4. Capability to configure, record, and retrieve snapshots of system parameters for selected faults or configured events. Refer to T 16.06 and T 16.07, Vehicle Monitoring System, Subsystem Integration and Fault Management Description for details.

B. The Trainline Functional Safety Self-Test shall test the functional operation of the brakes on each car in a train including the activation and de-activation of the slide control dump valves while monitoring brake cylinder pressures. The Trainline functional Safety Self-Test shall be initiated from the Operator Cab with the Master Controller active, the reverser switch in forward direction and the Power Handle in the Full Service Brake position. Any faults shall be reported to the Vehicle Monitoring Unit for display to the Operator.

1. The Trainline Functional Safety Self-Test shall test the brakes on each car in sequence so that the train does not roll during testing.

12.04.03. Fault Logging and Snapshots

A. Sufficient data shall be recorded with each fault to enable maintenance personnel to isolate the fault to a line replaceable unit.

B. Fault and snapshot data shall be stored in non-volatile flash memory.

C. Flash memory requirements and management shall conform to the requirements of T 16.06, Vehicle Monitoring System, Subsystem Integration.

D. The FBCU shall report all faults and all design specified brake system parameters to the Vehicle Monitoring Unit as described in T 16.06, Vehicle Monitoring System.

E. The FBCU shall have the capability to record and store event and fault triggered snapshots.

The Contractor shall provide PTU software to download and display snapshots from the FBCU as specified in T 16, Vehicle Monitoring System.

12.05: AIR SUPPLY

12.05.01. Air Supply Configuration

A. The Air Supply System shall consist of the following:

1. Air compressor (one per Married Pair only).

2. Main Reservoir (1 per car).

3. Supply Reservoir (1 per truck).

4. Main Reservoir Trainline.

5. Other air reservoirs as required.

B. The Air compressor shall feed the Main Reservoir through a check valve to prevent loss of train air during a compressor or hose failure.

C. The Main Reservoir shall feed each Supply Reservoir through a check valve to prevent loss of all braking air due to a problem with the Main Reservoir Trainline Pipe.

12.05.02. Air Compressor

A. The air compressor unit shall consist of a reciprocating type compressor with a 3-phase 230 VAC, 60 Hz drive motor, electrical governor, input air filter, intercooler, after-cooler, oil/water separator, sump reservoir with an automatic heated drain valve, two-chamber (twin tower) regenerating desiccant air dryer and post-dryer filter.

1. The filter medium shall have a minimum life of 1 year and housings shall have moisture indicators to show when the desiccant requires changing.

2. The dryer chambers shall be cycled between absorbing and releasing water such that the compressor duty cycle shall not affect drying capability.

3. The automatic drain valve heater shall be powered by 115 VAC and have its own thermostat.

B. An LED located on the side of the Air Compressor control box shall indicate current flow through the air compressor drain valve heater.

C. The air compressor shall be sized so that one compressor can supply all air requirements of 4 cars in the event of a failure of another compressor in the train-set. The compressor shall be designed for continuous duty, in the event of such a failure.

D. The air compressor unit shall be a low-noise, low-vibration unit, service proven in the rail transit environment. Within the assembly, the motor/compressor shall be mounted on isolation mounts to minimize vibration, including minimizing the response of the carbody structure. The motor shall be fully enclosed and self-cooled.

E. The air compressor system shall provide sufficient dew point depression and temperature control to eliminate the possibility of freezing of any component in the friction brake and pneumatic systems. Refer to T 02, Vehicle Design Requirements, General, for the range of environmental conditions. The air compressor system shall prevent the buildup of moisture in pneumatic systems even under the most rapid changes in ambient humidity and temperature.

F. Failure of a compressor or its output hose shall not vent the Married Pair Main Reservoir.

G. The compressor shall have a pressurized oil lubrication system with an oil filter. The compressor shall have a readily accessible exterior sight glass and level markings for monitoring oil level.

H. The air compressor shall have a high pressure/low pressure electrical governor for control of the drive motor. The governor shall cut in at 130 ± 2 psig and cut out at

150 ± 2 psig. Positive action of the governor pressure switch shall not be influenced by a slow rate of depletion of the Main Reservoir pressure. The pressure switch shall be adjustable, positive in action, and able to function under all specified operating conditions. A safety valve shall be provided between the air compressor and the Main Reservoir to limit maximum system pressure to 165 psig.

I. In addition to the high pressure /low pressure electrical governor control of the Air Compressor drive motor, a trainline network control system shall be provided to distribute cycling evenly among all compressors on the train.

J. Air compressor failures shall be reliably detected and reported to the VMS for display to the Operator.

12.05.03. Reservoirs and Drain Valves

A. Reservoirs shall be low alloy steel with enamel or approved alternative coating inside and out. Reservoirs shall be designed to withstand 5 times the maximum pressure and comply with ASME Boiler and Pressure Vessel Code of Unfired Pressure Vessels, Section VIII and IX. All reservoirs shall also be provided with "telltale holes" in accordance with 49 CFR part 229.31.

B. There shall be one Main Reservoir on each vehicle. All non-braking air shall be drawn from the Main Reservoir or Main Reservoir trainline pipe. The Main Reservoir shall have a heated automatic drain valve. The Main Reservoir shall be positioned so as to locate the drain valve where it is easily visible from the side of the car. The Main Reservoir shall have a ball cock valve with a locking handle to allow evacuation for maintenance. The Main Reservoir shall have two side inspection holes with plugs (1.5 inch - 11.5 NPT).

C. The automatic drain valve shall operate on a timed schedule.

D. A second LED light on the side of the Air Compressor Control Box shall indicate current flow through the Main Reservoir drain heater.

E. A Supply Reservoir shall be supplied for each truck. Only friction braking air pressure shall be supplied by the Supply Reservoir. Air shall be supplied to the Supply Reservoir by the Main Reservoir with protection against loss of air pressure by means of a suitable check valve located in the Supply Reservoir inlet. The Supply Reservoir shall have a removable drain plug (0.5 inch - 14 NPT). The Supply Reservoir shall have sufficient capacity for 5 service brake applications followed by one emergency brake application.

F. The Main Reservoir shall have sufficient capacity for simultaneous operation of the friction brakes and all other pneumatic systems on the car, including leveling valve cycling.

G. A Main Reservoir Pipe pneumatic trainline shall be provided equalize the Main Reservoir pressure and air compressor duty cycles. The Main Reservoir Pipe shall also allow a Married Pair with an inoperative compressor unit to be charged from adjoining vehicles. A means shall be provided at the No.1 end's Main Reservoir

Trainline, to minimize air loss due to a coupler failure while allowing sufficient air flow to supply the air requirements of an adjacent vehicle with a failed compressor.

H. There shall be no water traps in the Main Reservoir Pipe.

I. The Main Reservoir air system shall provide air for the air spring system, coupler controls/operation, coupler centering devices, horn, and other equipment as may be needed. Each of the additional systems powered from the air system shall:

1. Have a cutout cock to remove the system's air supply in the event of a malfunction. The cutout shall allow for continuation of normal compressor and brake operation by isolating the malfunctioning system.

2. Have a filter or strainer in the line.

J. The Air Spring system shall have a check valve in line between the leveling valves and the Main Reservoir.

12.06: PERFORMANCE

12.06.01. Friction Brake Build Up times

A. Service friction brake build-up and release rates shall meet the jerk rates and response times specified in T 02.02, Vehicle Design Requirements, Performance.

B. Emergency friction brake rates and emergency brake build up times shall be as specified in T 02.02, Vehicle Design Requirements, Performance.

12.06.02. Emergency Brake Pipe Charging and Evacuation

A. The time required to charge the Emergency Brake Pipe of a 6 car train shall not exceed 10 seconds when starting with a Main Reservoir pressure of 130 psig or greater.

B. The time to 90% reduction of the Emergency Brake Pipe pressure in the last car of 6-car train shall not exceed 1.8 seconds when vented from the lead car trip cock with pneumatic propagation only.

12.06.03. Fading and Thermal Capacity

A. The Brake system shall meet the friction brakes only duty cycle described in T 02.02, Performance, without degradation of the service and emergency brake rates below the levels specified in that section. Brake shoe and wheel temperature limits shall not be exceeded during the test. No damage to the brake equipment or wheels shall occur as a result of continuous friction brake only operation.

12.06.04. Noise Levels

A. Noise levels shall not exceed the external noise limits defined in T 02, Vehicle Design Requirements.

12.06.05. Snow Brakes

A. The final pressure setting shall be determined during pilot car testing. The snow brake pressure setting shall be coordinated with the All Brakes Released function so that the snow brake application will not influence the operation of the All Brakes Released Trainline.

12.06.06. Wear Rates

A. The brake shoes shall have a minimum wear life of 50,000 miles in normal service where dynamic braking is active. Snow brakes may be applied during snow or sleet storms. Otherwise, friction brakes shall normally only be applied during low speed brake fade and during full service braking on AW3 cars at speeds above 42 mph. At lower vehicle loading or lower braking efforts there may be little or no friction brake blending at higher speeds. (See T 2.02.03 Performance, Dynamic (Electric) Brake.)

12.06.07. Air Supply Capacity

A. One air compressor shall be able to supply all air needs of 4-cars in normal service without overheating or suffering any damage. This shall be verified at the Qualification test.

B. The Supply Reservoir shall have sufficient storage capacity such that starting from 130 psig with no additional air from the Main Reservoir:

1. It shall be possible to make five full service brake application/release cycles of 10 seconds apply and 30 seconds release, at a vehicle weight of AW3.

2. After the 5 service brake applications sufficient capacity shall remain to make one AW3 emergency brake application.

12.06.08. Air Supply Quality

A. The Air Supply System shall meet the requirements of APTA SS-M-011-99 Standard for Compressed Air Quality for Passenger Locomotive and Car Equipment, section 4.2, Air Quality Criteria.

12.06.09. Air Supply System Leakage Rates

A. Leakage from the air supply system with a vehicle at AW3 and maximum brake application shall not cause a drop of more than 10 psig in 15 minutes starting 5 minutes after the air compressor shuts off at 150 psig.

12.06.10. Parking Brake

A. The Parking Brake shall meet the performance requirements of T 02.02.09, Vehicle Design Requirements, Performance, Parking Brakes.

B. The mechanical release and re-apply mechanisms shall be operable by a 5th percentile female.

12.07: QUALIFICATION TESTING

12.07.01. General

A. The testing requirements are broken out into tests conducted on the individual components and tests conducted on the Pilot Cars. Component tests are listed in this section and Pilot Car tests are included in T 20, Testing & Validation.

B. Procedures for the tests listed in this section shall be submitted for Authority review and approval. [CDRL 12-05]

C. Test Reports shall be submitted for Authority review and approval. First Article Inspection (FAI) acceptance shall be subject to successful completion of the tests. [CDRL 12-06]

12.07.02. Component Qualification Tests

A. Component qualification test performed by the Contractor shall include, but not be limited to:

1. Golden shoe force test of Service Brake and Emergency Brake application
2. Golden shoe force test of Parking Brake application
3. Emergency Brake build up time
4. Dynamometer test of brake shoe wear rates
5. Dynamometer test for compliance with friction brake only operation
6. Brake shoe and wheel noise test
7. Parking Brake resistance and functional tests
8. Snow brake functional test
9. Slide control functional test
10. Speed sensor failure test
11. Air spring failure test
12. Functional Test of the Air Compressor and the Air Dryer
13. APTA Air Quality Test
14. Compressor Air Volume Test.

12.07.03. Factory System Integration Tests

A. The Contractor shall perform the following system integration tests:

1. The Contractor shall comply with the Vehicle Monitoring System integration testing requirements of T 16, Vehicle Monitoring System.

2. The Contractor shall comply with the Network Integration Testing requirements of T 24, Trainlines & Networks.

3. The Contractor shall verify compliance with the propulsion system and the Friction Brake Control Unit Interface Document described in T 10.07.04, Friction Brake Control Unit Interface.

12.08: RELIABILITY

12.08.01. Mean Distance between Component Failures

A. Mean Distance between Component Failures (MDCBF) for the overall brake and air supply system shall be 80,000 miles.

12.08.02. Overhaul Period

A. Air brake system valves shall not require scheduled maintenance at intervals of less than four years.

B. The Air Supply system and tread brake units shall have a minimum of seven (7) years between scheduled maintenance overhaul.

12.09: MAINTAINABILITY

12.09.01. Maintainability Requirements

A. All airbrake components shall have sufficient clearance with surrounding structure, conduits, and air lines for removal and troubleshooting.

B. All valves shall be clearly marked with permanent identification labels, using raised letter, stainless steel nameplates with backfilled paint. Manifolds may be identified with engravings.

C. All valves, and tread brake units, shall have attached Asset Identification Tags per section T 22, Systems Assurance.

D. Any pneumatic components that may require regular maintenance shall be equipped with a cutout valve to facilitate the maintenance. This includes but is not limited to:

   1. The Brake Valve Manifold Unit and associated filter

   2. The Emergency Brake Pipe Control Unit.

E. A locking cutout valve and a male fitting for connecting shop air shall be provided on the main reservoir.

F. Test fittings and air supply fittings shall have stainless steel protective caps with stainless steel security chains.

G. Piping shall be stainless steel welded tubing, except where required for ease of maintenance.

H. All airbrake valves shall be attached to pipe brackets on studs with metric nuts of standard sizes.

I. Piping and hoses shall be protected at all brackets and carbody components against chafing. This will be demonstrated at the inter-car and carbody and truck swivel test at AW0 through AW3 weights.

J. A maintainability demonstration will be conducted for Authority approval in accordance with T 02.04, Vehicle Design Requirements, Maintainability. [CDRL 12-07]

K. All consumable parts/fluids of the compressor unit (e.g. air filters, desiccant elements, oil) shall be designed to require replacement or renewal no more often than once a year with an expected annual mileage of 50,000 to 70,000 miles. The time required to replace any consumable air compressor item shall not exceed 20 minutes by one person. All non-consumable parts of the compressor shall be designed to be replaced or renewed no sooner than once every 6 years.

12.10: SAFETY

12.10.01. General

A. This section identifies specific hazard conditions that the Contractor shall address with respect to the friction brake system. It shall not be considered as all inclusive and the Contractor shall be responsible for ensuring that the safety analyses for the friction brake system is complete and inclusive for the design used.

12.10.02. Loss of Air

A. Loss of air pressure below 80 psig in Emergency Brake Pipe shall cause an irretrievable emergency brake application.

B. Loss of air pressure in the Main Reservoir below 80 psig shall cause an irretrievable emergency brake application.

12.10.03. Trainline conflict

A. Conflicting trainlines between the brake or power level request and the brake or power mode requested shall result in removal of power and a full service brake application.

12.10.04. Speed Sensor Failure and Slide Control

A. Slide control on any truck shall be disabled if dynamic and friction brakes are released continuously by the slide control for more than 3 seconds.

12.10.05. Warning of Brake Failure to Apply

A. Failure of the friction brake system to produce requested brake cylinder pressure at the truck (measured after the slide control magnet valve) for more than 4 seconds when no slide is detected shall produce a brake failure fault warning. The fault warning shall be annunciated to the Operator on the Vehicle Monitoring Display (VMD) identifying the car number and truck. The brake failure fault shall continue to be displayed on the VMD until the friction brakes are serviced.

B. The brake failure warning function shall be disabled for a truck when the BCO handle is in the cut out position.

C. When brakes are cutout on any truck the Brake Cut Out warning shall be displayed on the VMD.

12.10.06. Failure of the FBCU Self Test.

A. Failure of the FBCU system start up fitness for service test shall prevent the release of the service brakes on the truck until the unit is serviced and the faults cleared.

B. FBCU failures that may result in a hazardous event at any time shall result in transition to a more restrictive state.

12.10.07. Trainline Functional Safety Self- Test

A. Failures of the Trainline Functional Safety Self Test described in T 12.04.02 shall be announced to the operator on the Vehicle Monitor Display. Critical failures shall force reduced performance of the train until the car is removed from the train and the system is repaired.

12.10.08. Safety Analysis

A. The contractor shall evaluate the safety of the friction brake system in accordance with T 02.06, Vehicle Design Requirements, Safety. A Failure Modes Effect and Criticality Analyses (FMECA) of the Service and Emergency Brake Systems shall be provided for the Authority's Review and Approval. [CDRL 12-08]

B. A FMECA of the spin/slide system hall be provided for the Authority's Review and Approval. [CDRL 12-09]

12.11: COMPATIBILITY

12.11.01. Interchangeability

A. All friction brake components and subsystems shall be interchangeable between the Red and Orange Line Vehicles with only re-configuration or adjustment.

12.12: CDRL ITEMS REFERENCED

CDRL 12-01, “Functional Description of the Friction Brake and Pneumatic System”, (Ref: T 12.01.F)

CDRL 12-02, “Certification of Brake Supplier Approval of Application”, (Ref: T 12.01.H)

CDRL 12-03, “Parking Brake Design”, (Ref: T 12.02.12.G)

CDRL 12-04, “Cutout and Test Manifold Location and Design”, (Ref: T 12.02.14.J)

CDRL 12-05, “Test Procedures”, (Ref: T 12.07.01.B)

CDRL 12-06, "Test Reports", (Ref: T 12.07.01.C)

CDRL 12-07, “Maintainability Demonstration”, (Ref: T 12.09.01.J)

CDRL 12-08, “FMECA of the Service and Emergency Brake System”, (Ref: T 12.10.08.A)

CDRL 12-09, “FMECA of the Spin/Slide System”, (Ref: T 12.10.08.B)

12.13: REFERENCES

12.13.01. Standards Referenced

ASME Boiler and Pressure Vessel Code of Unfired Pressure Vessels, Section VIII and IX.

49 CFR Part 229.31

12.13.02. Technical Specification Cross References

T 02, Design Requirements
T 10, Propulsion & Dynamic Braking
T 11, Trucks
T 14, Interior & Exterior Appointments
T 16, Vehicle Monitoring System
T 18, Materials & Workmanship
T 20, Testing & Validation
T 22, Systems Assurance
T 24, Trainlines & Networks

PART T 13.00
COMMUNICATIONS & PASSENGER INFORMATION SYSTEM

Table of Contents

13.01: GENERAL

13.01.01. System Features

A. The Contractor shall provide, install and configure a communications system that provides reliable and intelligible communications between:

1. The train and the Operations Control Center (OCC).

2. Crew members.

3. Passengers and crew, in case of a passenger emergency.

B. The contractor shall also provide a passenger information system that informs passengers of station stops, connections, train route and special announcements in audio and visual format.

C. The communications system shall be of a digital design with train wide and intra-car communication based on the Digital Network described in T 24.03, Digital Networks.

D. Each married pair vehicle shall be provided with provisions for installation of an IEEE 802.11 Standard compliant High Density Data Radio (HDDR) to allow vehicle systems to communicate with the OCC and with maintenance databases.

E. The Contractor shall also provide a Closed Circuit Television System (CCTV) to record and display views of the passenger compartment and of the Right of Way (ROW) directly in front of the train.

F. The Contractor shall propose an Automatic Passenger Counting System (APC) that automatically counts all passengers boarding and exiting the train at each door. (OPTION)

G. The contractor shall also provide and install the Authority selected wayside worker warning system for warning the train Operator of the presence of work crews and work crews of an approaching train.

13.02: SYSTEM DESCRIPTION & CONFIGURATION

13.02.01. General

A. The Contractor shall submit, for review and approval by the Authority, a functional description of the communications system proposed to provide the services listed in this section. [CDRL 13-01]

B. The Contractor shall supply the following communications systems:

1. Train Radio for voice and low density data communications with the OCC.

2. Crew Intercom for communications between cabs on the train.

3. Passenger Emergency Intercom (PEI) for emergency communication between the crew and a passenger.

4. Public Address (PA) System for announcements from the Crew, or the Dispatcher, or the Automatic Announcement System to all passengers in all cars.

5. An LED Front Destination Sign on each Cab Car and Exterior LED Side Destination Signs on each side of each car, two on each side for the Orange Line cars and three on each side for the Red Line cars.

6. A Passenger Information System which shall allow automatic and special announcements to be made in audio and visual formats to the passengers with regard to stations, destinations, delays and emergencies

7. LED active route maps. (OPTION)

8. LCD displays for additional passenger information and active route maps with the capability to display advertisements. (OPTION)

9. A CCTV system for passenger security.

10. An Automatic Passenger Counting System (APC). (OPTION)

11. Provisions for a HDDR for transferring data to and from the wayside, including wiring, circuit protection, antennae mounting, and other peripherals as needed.

12. An authority specified Wayside Worker Warning System

C. All communications systems described in this section, with exception of the Train Radio and the Wayside Workers Warning System, shall be digitally based with networking through the Ethernet networks described in T 24.03, DIGITAL NETWORKS.

13.02.02. Installation

A. The Train Radio Control Head for the Cab Car shall be mounted in or adjacent to the Communications Control Panel (CCP) located as described in T 05.03, Cab Controls. The Train Radio transceiver shall be installed in a location in the cab where it is easily accessible for removal and replacement. All wiring and cables for the Train Radio shall be compliant with the radio manufacturer's requirements and the requirements of T 18, Materials & Workmanship. All wiring to the Train Radio transceiver and Train Radio control head with the exception of the coaxial antenna cable shall be through multi-conductor connectors.

B. All wiring to the CCP shall be through multi-conductor connectors.

C. A second Train Radio control head shall be installed in the Non-Cab Car. The control head and a Communications Control Panel shall be installed in an enclosure near the Hostler Panel as described in T 05.05, Non-Cab Cars. The radio transceiver shall be located in an accessible area on the No. 1 end of the Non-Cab

Car. All wiring and cables for the Non-Cab Car Train Radio shall meet the same wiring and cabling requirements as the Cab Car Train Radio.

D. Automatic Announcement Control Panel (AACP) shall be provided in the Operator's Cab located adjacent to the CCP, as described in T 05.03, Cab Controls. The AACP shall allow the train crew to control destination signs, control automatic station announcements and select special pre-recorded voice and text messages to be broadcast and displayed to the passengers.

E. All wiring connections to all electronic signs and all PEI units shall be through multi-conductor quick-disconnect connectors.

F. All wiring carrying control, data and analog audio signals as well as power for the communications system shall be run in separate conduits from wiring for other vehicle systems.

G. Shields and communications circuits shall be arranged to prevent ground loops and to avoid the shield from becoming a return conductor for vehicle power circuits. Shields shall be terminated per T 18.13, Wiring.

H. A Communications Control Rack (CCR) shall be mounted in an enclosure inside each Cab Car in an area accessible for maintenance. The control equipment, digitizers, pre-amplifiers, and amplifiers, etc. for all functions other than Train Radio and shall be located in the CCR. The CCR shall contain easily replaceable modules that provide the required functionality.

I. Connections from the CCRs within the Married Pair vehicle to PA speakers, Crew Intercom, PEI, LED Announcement Signs, and Destination Signs shall be designed to provide at least 50 per cent redundancy. So that, for example, loss of single PA amplifier shall not disable more than 50% of the speakers in any one car.

J. Cab speakers shall be provided in locations described in T 05.03 Cab Controls.

K. A minimum of 8 PA speakers shall be provided and installed in the passenger area as described in T 14.02.07, Interior Speakers, to achieve a uniform distribution of announcements throughout the car.

L. All wiring to the CCR shall be through multi-conductor connectors.

M. All Ethernet Network wiring shall be through M12 connectors.

N. All analog audio signals shall be carried in twisted shielded pairs.

O. Destination sign locations shall be as described in T 14.02.14, Exterior LED Destination Signs.

P. The LED Active Route Maps shall be installed in the locations described in T 14.02.13, LED Displays. (OPTION)

Q. Transverse LED Station Announcement Signs shall be installed over the aisles as described in T 14.02.11, Transverse LED Announcement Signs.

R. All interior LED signs and exterior side destination signs shall be mounted in vandal resistant enclosures.

S. An antenna shall be mounted under each Cab Car for reading RFID station identification tags mounted in the track bed.

T. Conductors shall be sized based on the current-carrying capacity, mechanical strength, temperature, flexibility and voltage drop. The Contractor shall comply with all wiring and cable requirements of T 18.12, Wire and Cable.

13.02.03. Power

A. The Communications System shall be powered from the DC low voltage distribution system and shall contain all power conversion and power conditioning devices required for reliable performance. All communications equipment shall be operate without failure within the entire voltage range of the Low Voltage System as described in T 02, Vehicle Design Requirements.

B. The Cab Car and Non-Cab Car Train Radios shall be powered off separate low voltage DC circuit breakers, and each shall have its own separate conditioning power supply.

C. The Train Radio conditioning power supplies shall meet the power requirements specification of the radio supplier.

D. Exterior LED Destination signs shall be powered from a separate circuit breaker.

E. A Separate circuit breaker shall be provided for the LED Transverse Announcement Signs.

F. A Separate circuit breaker shall be provided for all other LED and LCD displays and maps.

G. Each subsystem in the CCR shall have its own separate circuit breaker and it own separate conditioning power supply. The Contractor may propose alternatives to power redundancy, but as a minimum, PA amplifiers, network interface modules, and intercom/audio control modules shall have separate circuit breakers and power supplies.

H. Power wiring for the CCR shall meet or exceed the requirements of the latest version of IEEE STD 1477 and T 18.12, Wire and Cable.

I. The power interface for all communications equipment, including signs and displays, shall be protected against voltage transients of up to 2.5 kilovolts for 80 watt seconds, electrical short circuits, ground faults and reverse polarity. The power interface for all communications equipment shall meet all other requirements of the latest version IEEE STD 1477. The contractor shall provide test results showing the equipment provided meets the power interface requirements of IEEE STD 1477. If the compliance of the equipment provided has been tested and certified for previous projects, the previous test results may be provided for review. [CDRL 13-02]

J. The contractor shall provide a block layout and power distribution design for the communications systems prior to the Preliminary Design Review for review and approval by the Authority. [CDRL 13-03]

13.02.04. Train Radio System

A. The contractor shall supply and install the latest (M/A-COM) revision Train Radio that is backward compatible with the M/A-COM M7100IP mobile radio with Enhanced Digital Access Communication System (EDACS), Digital Trunking Transceiver and Control Head.

B. The supplied radio shall:

1. Transmit in the 806 MHz to 809 MHz band
2. Receive in the 851 MHz to 854 MHz band
3. Be fully compatible with the M/A-COM ProVoice digital voice technology
4. Have equivalent transmitter power ratings as the M/A-COM 7100IP
5. Have additional attenuation available for transmitter power to allow a minimum RF power output of 8 watts
6. Be compatible with the Authority's EDACS digital trunking system
7. Have 12 to 15 watt speaker output power
8. Meet all Federal Communications Commission (FCC) bandwidth and emission requirements
9. Power up in less than 3 seconds

C. The Contractor shall provide and install a low profile, radome type antenna on the roof of each car compatible with the transceiver provided.

D. The antenna shall be connected to the transceiver with a coaxial cable and Radio-Frequency (RF) connectors approved for use by the radio manufacturer and accepted by the Authority.

E. A Metal FCC certification tag shall be affixed to the Train Radio transceiver.

F. The Cab Car Train Radio shall be powered any time battery power is available.

G. The Non-Cab Car Train Radio shall be powered any time battery power is available and the Hostler Panel is keyed up.

H. The Train Radio shall automatically identify the car number for each transmission.

I. The Cab Car Train Radio shall have the capability of energizing a relay to connect its speaker output to the PA system on command from the OCC.

J. The Cab Car Train Radio speaker output shall be connected to the cab speakers at all times when the handset is not being used in the radio mode.

K. The Non-Cab Car Train Radio speaker output shall be connected to a speaker mounted in the Hostler Panel enclosure. The speaker shall be active at all times when the Hostler Panel is active (keyed up) and the radio handset is not off the hook.

L. A Radio Data Interface (RDI) converter shall be provided with an RS232 interface with the Train Radio. The RDI shall convert discrete inputs to RS232 serial communications for transmission to the OCC. The following discrete inputs shall be transmitted to the OCC:

1. ATP Emergency Bypass active
2. ATP in Manual Release mode
3. ATP in Hostler Release mode
4. Silent Alarm
5. PEI session request

M. The Train Radio shall be connected to a telephone style handset through the Communications Control Panel (CCP)

N. In the event of a failure of the CCP, the default connection to the handset shall be the radio.

13.02.05. Digital Audio

A. The core of the PA and intercom systems shall be of a digital design with transfer of audio signals between locations in the train over the vehicle and train wide digital network described in T 24.03, Digital Networks. All audio signals shall be transmitted over this network using IEEE 1473 Type E approved protocols.

B. Each CCR shall have a processor with channels to convert handset and PA microphone inputs and radio speaker inputs to digitally encoded audio signals for transmission to other handsets and PA amplifiers.

1. Noise cancelling microphones that are impedance matched to channel inputs shall be used.
2. Pre-amplification, compression and noise cancellation techniques shall be used to reduce total harmonic distortion to less than 2% and to reduce the interference from ambient noise.

3. Discrete inputs such as PA Push to Talk (PTT), "Intercom", "Passenger Emergency Intercom" and "Radio" pushbuttons shall also be processed for system control.

C. Each CCR shall have circuitry to convert digital signals to analog and amplify signals for cab speakers, earphone of the CCP handset and passenger area speakers as needed.

D. Each PEI station shall have its own analog to digital and digital to analog processing circuitry to convert microphone input to digital signals and convert digital signals received from the crew to analog speaker output.

E. PA, Crew Intercom, PEI and the digital networks shall be available for use within 30 seconds of power on.

13.02.06. Communications Control Panel

A. Communications Control Panels (CCP) shall be mounted:

1. In the cab adjacent to the Operator's control panel

2. In an enclosure near the Hostler Panel in the Non-Cab Car

B. A telephone style handset with a PTT key shall be mounted on a hook on the CCP. The handset shall be connected to the radio unless another mode is selected.

C. The CCP shall include the following controls and indications:

1. LED pushbuttons labeled:

a. "Crew Intercom"

b. "PEI"

c. "Radio"

2. LED indicator for Radio Power

D. Pressing the PTT key on the handset when no other mode is selected activates radio transmission of input from the handset microphone.

E. By default, removing the handset from the hook connects the earpiece to the Radio and disables the cab speakers.

F. All electrical connections to the CCP shall be made through multi-conductor quick disconnect connectors.

13.02.07. CCP Operation of the Crew Intercom System

A. Removing the handset from the hook when the CCP is in PEI or Crew Intercom mode does not disconnect the radio from the cab speakers.

B. Momentarily pushing the Crew Intercom pushbutton in any cab shall cause the Crew Intercom LED pushbutton in all cabs to flash and cause a unique one second sound to be played on the cab speakers. The communication system shall alert the Vehicle Monitoring System when any Crew Intercom pushbutton is activated to request a session. The Vehicle Monitoring System shall announce the request and the car of origin on all active Vehicle Monitoring Displays (VMD).

C. When the Crew Intercom LED pushbutton is pushed in a second cab, a crew intercom session is established which will allow crew members to talk to each other with the handsets as if on regular telephone. Additional crew members may join the conversation by picking up the handset in another cab and pushing the Crew Intercom pushbutton.

D. Selecting another mode such as "Radio" or "Passenger Emergency" shall put the Crew Intercom session on hold. Pressing the Crew Intercom pushbutton again shall restore the Crew Intercom session.

E. Returning the handset to the hook shall cancel the Crew Intercom session.

13.02.08. CCP Operation of the PEI System.

A. When a PEI unit is activated in any car, the "PEI" LED pushbutton shall flash until the PEI request is acknowledged by a member of the crew. A distinct audible alert shall sound in all cabs for 10 seconds unless the PEI request is acknowledged by a member of the crew. When a crew member in any cab acknowledges the PEI request by pushing the "PEI" LED pushbutton, a PEI Session shall be established. "PEI" LED pushbutton shall be in a steady ON condition in that cab and the audible alert shall cease. In all other cabs the "PEI" LED shall continue to flash, however the audible alert shall cease. The handset in the responding cab shall be active in the PEI mode. Two way communications with the PEI unit in the remote car through the handset shall take place as if over a telephone.

B. If a second PEI request is received during a session, the "PEI" LED pushbutton shall resume flashing.

C. A crew member shall be able to acknowledge any additional PEI sessions by pressing the "PEI" LED pushbutton. In this case, the crew member shall be able to listen to the additional PEI station as well as the previous PEI station(s). All PEI stations with active sessions shall also be able to hear the crew member.

D. A second crew member shall be able to join the session by pressing the "PEI" LED pushbutton in another cab.

E. Pressing the "Radio" or "Crew Intercom" pushbutton shall put the PEI session on hold and transfer the handset to the radio or crew intercom mode. If another crew member has joined the session from a second cab the communications between the second crew member and the passenger at the PEI shall continue.

F. Pressing the "PEI" pushbutton again shall restore the handset to the PEI session.

G. Returning the handset to the CCP hook shall cancel the PEI session. If more than one crew member from more than one cab has joined the PEI session all handsets must be returned to the CCP hook.

13.02.09. PEI Stations

A. PEI Stations shall be provided and installed in the locations described in T 14.02.08, Passenger Emergency Intercoms.

B. The design for the PEI stations shall be submitted for Authority review and approval prior to the Preliminary Design Review. [CDRL 13-04]

C. The PEI Station shall consist of a panel mounted enclosure with a stainless steel face which shall enclose a speaker, microphone, large (1.5 inches in diameter) recessed pushbutton switch, a status LED light, and the necessary circuitry and components to make the system function. The PEI Station shall also have a second LED light integrated into the pushbutton which shall be on at all times to assist the visually impaired in locating the unit.

D. The PEI station shall be of splash-proof, vandal-resistant construction with components designed for severe transportation duty.

E. Electrical and network connections shall be made through concealed multi-pin connectors.

F. The microphone shall be provided with external filters to reduce background noise.

G. The speaker shall have a minimum rating of 5 watts.

H. The PEI station shall be digitally based and connected to the Digital Network.

I. The PEI speaker amplifier shall include ambient noise sensing and automatic level compensation.

J. Operation of the PEI station shall be as follows:

1. When the pushbutton switch is pressed:

   a. A PEI session request shall be latched.

   b. The status LED light on the PEI station shall begin flashing.

   c. An output from the CCR to the Vehicle Monitoring Unit shall inform the VMS of the PEI request and the car number of the PEI station activated. The VMS shall display a PEI alert and the car number on the VMD.

   d. A discrete output from the CCR to the radio interface shall initiate a message to the Operations Control Center (OCC) that a PEI request has been made.

e. A view from the CCTV camera with the best view of the first PEI station activated and a longitudinal view of that car shall be automatically transmitted to the CCTV display in the cab set up for door control.

(1) If the cab set up for door control is also the operating cab, the display shall not activate until the train comes to a stop.

2. When a crew member acknowledges the PEI request, the status LED light on the PEI station goes to steady ON and two-way conversation may begin without any further action by the passenger.

3. If additional PEI stations are activated, the passengers that activated them may join the conversation as on a telephone party line.

K. When a Passenger Emergency Stop lever is activated a PEI session request shall automatically be initiated from the nearest PEI station. The system shall behave as described above when a passenger pushes the PEI pushbutton.

13.02.10. Passenger Information System Configuration

A. The Contractor shall provide a digitally based Passenger Information System consisting of:

1. A PA System

2. Transverse Announcement Signs

3. Destination Signs

4. LED Active Route Maps (OPTION)

5. LCD Displays (OPTION)

6. An Automatic Station Identification (ASI) system which shall read RFID tags mounted in the right of way in order to trigger automatic station announcements

7. An Automatic Announcement/Sign Control System (AASCS) which shall:

   a. Store pre-recorded voice and text messages

   b. Control the PA and Announcement signs to make voice and text station announcements upon a trigger from the ASI

   c. Make Operator selected pre-recorded announcements

   d. Make special announcements received from the OCC

   e. Index the Active Route Maps upon the ASI trigger

   f. Control the External Destination Signs

8. An Automatic Announcement Control Panel (AACP) on the operator's console which will allow the operator or door attendant to control announcements.

B. All Automatic Station Announcements, pre-recorded announcements and voice/text messages received from the OCC shall be simultaneously broadcast over the PA systems and displayed on the Announcement Signs.

C. Communication between networked elements of the Passenger Information System shall be over the CEN.

D. The HDDR and the CEN shall provide the train dispatcher with access to the Passenger Information System. The OCC shall be able to transmit simultaneous voice and text messages to be broadcast over the PA system and displayed on Vehicle Announcement Signs immediately. The OCC shall also be able to transmit voice and text messages to be broadcast periodically with a given priority and expiration time.

13.02.11. The Automatic Announcement Control Panel

A. The AACP shall communicate with the AASCS and:

1. Enable the train crew to broadcast selected pre-recorded audio and text messages to the passengers in all cars of the train.

2. Enable the crew to select pre-recorded audio and text messages and assign a frequency with which to repeat the message and the priority of the message. Generally, longer pre recorded messages shall by default be assigned a lower priority than automatic station announcement messages.

3. Enable the crew to select a route and destination or “out of service” which shall:

   a. Control the message displayed on the exterior destination signs.

   b. Control next station announcements and door side opening announcements.

   c. Configure all Interior Active Route Map Displays accordingly.

4. Enable the train crew to synchronize the Station Announcements and the Interior Active Route Map Displays in cases when the Automatic Station Announcement system gets out of synchronization.

B. The route and destination locations shall be stored in non-volatile memory. Higher priority messages shall take precedence over lower priority messages.

13.02.12. Automatic Announcement and Sign Control System (AASCS).

A. The AASCS shall store all route information, all automatic station announcements in voice and text, all pre-recorded voice and text special messages, and all special voice and text messages sent by the dispatcher over the HDDR in non-volatile memory.

B. The AASCS non-volatile memory shall be large enough to store voice and text automatic station announcements for 100 stations, voice and text for 100 twenty-word special messages, and the priority assigned to each active message.

C. The AASCS shall control the Destination Signs and the Active Route Map Displays. (OPTION)

1. AASCS shall control the Destination Signs and Active Route Map Displays (OPTION) according to the Route selected by the Operator on the AACP.

2. The AASCS shall index the Active Route Map Display (OPTION) when it receives a trigger from the Automatic Station Identification (ASI) tag reader upon leaving a station.

3. The AASCS shall automatically set up the Destination Signs and the Active Route Map Displays for the return trip when the train doors open upon entering the last station on the route. The new set up shall remain in effect when the Operator changes controlling ends of the train. This function shall not be operable when the “Out of Service” Destination is selected on the AACP.

D. The AASCS on the lead car shall read the transponder code provided by the ASI tag reader and look up the appropriate pre-recorded audio and text announcement to be broadcast at each station.

E. When the train passes over the transponder at the entrance to a station, the AASCS shall control the PA system and Announcement Signs to make voice and text announcements of:

1. The station name

2. The side(s) upon which doors will open

3. Connection information

4. Relevant information about the station such as elevators out of service etc.

F. When the doors open in the station the AASCS shall control the PA system and Announcement Signs to make voice and text announcements of:

1. Train destination

2. Any other relevant information that may be agreed upon at design review.

G. When the train passes over the transponder at the exit of a station, the AASCS shall:

1. Control the PA system and the Announcement Signs to make voice and text announcements of:

   a. The next station name

   b. The side(s) upon which doors will open

c. Connection information

d. Relevant information about the station such as elevators out of service, etc.

e. When the train passes over the transponder at the exit of a station the AASCS shall index the Active Route Maps.

13.02.13. ASI RFID Tag Reader

A. The CCR on each Cab Car shall have an ASI tag reader.

B. The ASI tag reader shall power an under-car antenna to probe and read RFID transponders mounted in the track bed between the rails at the entrance to and exit from every station. The ASI tag reader shall be compatible with Transcore AT5118 rail tags.

1. The Contractor shall provide rail tags for each end of each station on both tracks. The Contractor shall program the rail tags to provide the ASI tag reader with a code identifying the station and the end of the station at which they are located.

2. The Contractor shall provide the equipment and software for programming the rail tags. The Authority will assume responsibility for installation of the tags in accordance with the contractors' instructions.

C. The ASI module shall provide the station codes received from the rail tags to the AASCS.

13.02.14. Transverse LED Announcement Signs

A. One 2-sided Transverse LED Announcement Sign shall be installed above the aisle in the middle of each car.

B. One single sided Transverse LED Announcement Sign shall be installed at each ceiling height transition or at each end of the passenger compartment if no ceiling height transition is required.

C. The Contractor shall provide signage that is fully compliant with the ADA signage requirements for character width, stroke-to-height ratio and ADA character separation.

D. The LED Transverse Announcement Signs shall be of a matrix design and display red characters against a black background. The signs shall display characters 1.7 inches high. Due to the large number of signs, the Authority may consider a smaller character height.

E. The signs shall be capable of displaying a minimum two rows of 25 characters. For messages exceeding 50 characters the sign shall have the ability to display segments of the message sequentially. The message display shall be pitched slightly downward to improve passengers' viewing angle and to reduce reflections from the ceiling.

F. Each message shall be displayed twice.

G. The transverse signs and their enclosures shall not extend down more than 6 inches from the ceiling.

H. Transverse Station Announcement Signs shall be active only when the interior lighting control trainline is active.

13.02.15. LCD Displays (OPTION)

A. The Contractor shall provide a color LCD display system consisting of LCD displays and a media controller for each married pair vehicle. LCD displays shall be installed as described in T 14.02.12, LCD Displays.

B. Each LCD display shall:

1. Be powered from the DC low voltage distribution network with circuit breaker protection and internal power conditioning power supplies.

2. Be equipped with an Ethernet port to receive content from the media controller and report status to it.

3. Be ruggedized to withstand the shock and vibration of a rail transit environment and mounted in a vandal resistant enclosure.

4. Be no more than 3.5 inches deep.

5. Have a viewing area diagonal of 17 inches or greater.

6. Have a high reliability, long service life, LED back light.

7. Have intensity sensing and compensation for brightness and contrast.

8. Be operational with an ambient temperature range of 0 °C to +60 °C and shall be installed in a temperature controlled environment.

9. Have adjustable resolution up to minimum of 1280/720 pixels.

C. LCD Displays shall only be powered when the interior lighting trainline control is active and the passenger area temperature is above 10 °C.

D. Due to rapid changes in technology, the Authority will consider proposals for alternate technologies, provided that the signs meet the reliability requirements of 13.07.01, Mean Time Between Failures.

E. Display content shall be provided to the LCD displays from a media controller. The media controller shall:

1. Interface with the AASCS to allow synchronization of advertising and passenger information announcements with station announcement system. The ability to prioritize message type shall be provided.

2. Have a minimum of 16GB of solid state drive data storage.

3. Have a network interface to the Married Pair Communications Ethernet Network to receive updates of passenger information and advertising content over the High Density Data Radio.

4. Have Ethernet interface ports to connect to the LCD displays that it controls.

5. Be ruggedized to withstand the shock and vibration of the transit environment.

6. Be capable of operating between -20 °C and + 70 °C.

F. The LCD display system shall display information about connections, service delays, elevators out of service, attractions at each station, etc.

G. The LCD display shall also display the Active Route Map information described in T 13.02.16 if that option is not being exercised.

13.02.16. Active Route Map Display (OPTION)

A. The Contractor shall propose an LED Active Route Map Display as described in T 14.02.13, LED Displays.

B. The Active Route Map Display shall be powered from the DC low voltage power system.

C. The Active Route Map shall be of a vandal resistant design.

D. The Active Route Map shall display all the stations with their names on the route. A red LED shall light for the current station as the train enters that station. Green LED's shall be illuminated for the remaining stations on the route. The LED's for stations already visited shall be dark.

E. The route map shall automatically reconfigure for the opposite direction of travel when the doors open at the last station on the route.

F. Active Route Maps shall be active only when the interior lighting trainline is active.

13.02.17. Development Software and Workstations

A. The Contractor shall provide to the Authority two workstations and software to develop passenger information audio and visual announcements and graphics. The software shall provide the ability to tag the content developed so that the AASCS may determine when and where it is to be played. Repeat announcements shall be given a frequency and a priority.

13.02.18. Exterior LED Destination Signs

A. Exterior Front Destination Signs shall be of LED matrix design capable of displaying variable sized characters up to 6 inches high. The sign shall have a displayable area of a minimum of 44 inches by 10 inches. Characters shall be LED illuminated yellow against a black background. The Front Destination Sign shall be capable of 2 row display with 4 inch characters. One Exterior LED Front Destination Sign shall be provided and installed on each Cab Car as described in T 14.02.14, Exterior LED Destination Signs.

B. Exterior Side Destination Signs shall be of an LED matrix design capable of displaying characters up to 6 inches high. The sign shall have a displayable area of a minimum of 32 inches by 8 inches. Characters shall be LED illuminated yellow against a black background. The Exterior Side Sign shall be capable of a 2 row display with smaller characters. Exterior LED Side Destination Signs shall be provided on each side of each car as described in T 14.02.14, Exterior LED Destination Signs.

C. The depth of the all destination signs shall not exceed 3 inches.

D. Destination sign character width to height ratio, spacing and stroke width to height ratio shall meet IEEE STD 1477 -1998 section 4.1.3 and ADA requirements.

E. All destination signs shall be active only when the interior lighting control trainline is active.

13.02.19. Public Address System

A. The Public Address System shall allow announcements to be made to all passengers in a train from any cab microphone, from the Automatic Announcement System, from the OCC through the Train Radio and through the High Density Data Radio (HDDR).

B. The Contractor shall provide cab microphones as described in T 05.03, Cab Controls.

1. The gooseneck and palm held push to talk microphones described in T 05.03, Cab Controls shall be provided with noise cancelling.

2. A "PA Talk" momentary switch shall be provided on the Operator's console to provide the Push-to-Talk feature of the gooseneck microphone.

C. All PA announcements shall be preceded by a chime, to be approved by the authority, to alert the passengers of the forthcoming PA announcement.

D. The PA amplifier arrangement shall provide separate audio output for:

1. Interior speakers.

2. Left Exterior Speakers.

3. Right Exterior Speakers.

E. Each interior speaker power amplifier shall be provided with an ambient noise sensing microphone. A measurement of ambient noise shall be made before each announcement and power output shall be adjusted for ambient noise and variations in input to maintain an intelligible signal above the ambient noise.

F. Interior passenger area speakers shall:

1. Be provided at least in the number described in T 14.02.07, Interior Speakers.

2. Be of a rugged transportation grade design capable of withstanding all environmental conditions described in T 02, Vehicle Design Requirements.

3. Be flush mounted.

4. Be provided with a rear enclosure to protect from dust and moisture and to better reflect sound, and a grill to protect from foreign objects.

5. Be distributed and sized accordance with the expected ambient noise levels in each section of the car.

G. Exterior speakers shall be provided in the number and installed and mounted as described in T 14.03.10, Exterior Speakers.

H. For automatic announcements, exterior speakers shall be active on the side where the doors open for each station. When the Operator selects adverse operation from the AACP, the activation of exterior speakers shall be changed accordingly.

I. The control of external speakers shall be configurable to reduce volume at selected stations during selected hours, and to block automatic announcements when trains are located in storage yards.

13.02.20. Wayside Worker Warning System

A. The Authority is currently in the process of evaluating wayside worker warning systems as a secondary safety system. The system shall provide automatic radio based audible warnings to both train Operators and wayside workers. The Authority intends to deploy the selected system on all new and existing vehicles system wide. It is expected that the Authority will have finalized its plans by the time vehicle design commences.

B. It shall be the responsibility of the Contractor to install the Authority’s selected system in all Cab Cars procured under this contract in accordance with the specifications of the manufacturer of the warning system.

C. The Contractor shall provide a separate circuit breaker for the wayside worker warning system.

D. The Vehicle Monitoring System shall monitor the health of the warning system and its transceiver and shall report any failure of the warning system on the Vehicle Monitoring Display.

13.02.21. Closed Circuit Television and Video Recording System

A. The contractor shall provide a CCTV system to improve passenger security.

1. The Contractor shall provide and install a minimum of 8 digital IP video cameras in the passenger area of each car as described in T 14.02.22, CCTV Cameras. Passenger area cameras shall provide views of each side door way and longitudinal views of the passenger compartment.

2. The Contractor shall provide 1 IP camera installed in the Operator's Cab with a view out the front of the Cab Car as described in T 05.04.01, Forward Facing Camera.

3. The cameras shall have adjustable resolution of at least 800x600 pixel with frame rates adjustable up to 30 frames per second (nominally set at 10 fps).

4. The cameras shall provide the latest MPEG-4, or other Authority approved video compression. Each camera shall deliver compressed video in real time to the Network Video Recorder (NVR).

5. All video cameras provided shall have a proven history of reliable operation on transit rail vehicles. All video cameras shall be mounted in vandal resistant enclosures. All cameras shall operate in the temperature range of 0 °C to 50 °C.

B. The CCTV cameras and recorder shall be powered and operate whenever any Master Controller in the train is keyed on. When the Master Controller is keyed off, the CCTV system shall remain active and continue recording for 10 minutes. While the train is keyed off, any motion detected in a car, or any event as defined 13.02.21.C.2.c, shall activate the CCTV cameras and recording system and keep the system running for 10 minutes after motion stops. The time period for system recording should be user configurable.

C. The Contractor shall provide a NVR for storage of all camera views.

1. The NVR shall be connected to the Married Pair Network to allow:

    a. Access to recorded or real time video from any camera through the digital network or from the wayside by way of the High Density Data Radio while it continues recording all cameras.

    b. Transfer of video to the cab monitors.

2. The NVR shall:

    a. Be of a hardened shock resistant design with a proven history of reliable use in a subway vehicle environment. The Contractor shall submit evidence of previous successful deployment and shock resistant design to the Authority for review and approval. [CDRL 13-05]

    b. Have storage capacity for 7 days of the streams from all IP cameras at 10 frames per second before overwriting.

c. Shall tag memory sections to prevent overwrites, for a user configurable period of time, of all camera stream recordings for 5 minutes before and 15 minutes after the following triggers:

(1) A PEI request

(2) Passenger Emergency Stop request

(3) Activation of the security switch by a crew member

d. Shall provide remote real time or post event viewing of video streams from any camera in the car through the digital network and the high density data radio.

e. Shall attach (upon OCC request) to the Authority's IP based station video network to provide the real-time look-in capability and post event review capability. The look-in capability shall provide ability to select the car and camera to be viewed.

f. Shall transmit a view of any active PEI station, Passenger Emergency Stop or ramp request to the CCTV monitor in the cab with door control active. (See T 5.03.11)

g. Shall have easily removable and replaceable hard disk or solid state drives to facilitate use as evidence.

h. Shall have a date and time source synchronized to the same date and time source used by the Event Recorder for purposes of synchronizing video events to the Event Recorder data.

D. The Contractor shall provide an IP based video monitor in each cab for display of CCTV camera views.

1. The video monitors shall be:

a. Powered from the low voltage DC power system

b. Multicolor LCD displays of 12.1 inch diagonal design

c. Hardened for shock and vibration

d. Service proven on rail transit vehicles

e. Mounted as described in T 05.03, Cab Controls

f. Active only in the cab configured for door control

E. If the Operator's cab is configured for door control, the video displays shall be active only when the train is stopped.

13.02.22. Automatic Passenger Counting System (APC) (OPTION)

A. The Contractor shall propose an APC system to count passengers boarding and exiting at every door.

B. The APC system provided shall have a record of previous successful implementation on subway (metro) vehicles with wide dual leaf doors and platform boarding.

C. The APC system shall be microprocessor based with data and fault recording capabilities, self diagnostics and Ethernet connectivity.

D. The APC system shall use an infrared or other non-mechanical system to detect passenger boarding or exiting.

1. The APC passenger detection system shall distinguish between passengers boarding and exiting and shall not count passengers standing in the doorway.

2. The APC shall count passengers only when the doors are open.

   a. Door status detection may be either internal or provided by the door or Vehicle monitoring system.

E. The APC system shall be integrated into the network.

1. All connections to the network shall be in accordance with the requirements of T 24 Trainlines and Networks.

F. The APC system shall receive station location, train composition, and train route information from the AASCS.

G. The APC system shall stamp the boarding and alighting data collected every time the doors are open with the station name and train composition and car number as well as time and date.

H. The APC shall have the memory capacity to store boarding and exiting data for all doors for 8 days assuming 20 round trips per day.

I. The APC system shall total the passengers entering and exiting for each married pair or train at each location.

J. The APC system or its data analysis software shall calculate the total onboard passengers and reset to zero at terminal stations without any Operator actions or interface.

K. The APC system shall use the network and have provisions to use the Wi-Fi High Density Data Radio to upload passenger data to wayside servers upon request.

L. The Contractor shall provide software and the required licenses for wayside servers for requesting, uploading analyzing, checking and displaying passenger data by time, date, route, train and location.

1. The Contractor shall assist the Authority in installing and configuring the server.

M. The Contractor shall install APC retrieval software on a minimum of 10 laptop PTUs.

N. The Contractor shall deliver to the Authority DVD copies of the server and PTU APC retrieval and analysis software along with all required licenses and equipment to use the software and to transfer it to other machines when necessary.

O. The APC system shall have a fault detection and diagnostic system capable of detecting and reporting all faults in the processing and detecting units. The diagnostic system shall be accessible over the network.

Once installed, the APC sensing and counting system shall not require calibration or adjustment for the life of the unit.

13.03: FAULT REPORTING AND DIAGNOSTICS

13.03.01. Fault reporting

A. The communications systems shall report all faults to the Vehicle Monitoring Unit in the vehicles where they are located. The Contractor shall submit a list and description of all communications system faults for inclusion into the VMS Fault Management Plan as required by T 16.07, Fault Management Description. Faults shall be reported to the VMU over the network.

B. The connection to all communications devices on the network shall be checked at least every 5 seconds. If a device fails to respond over a 20 second period, the communications failure of that device shall be reported to the Vehicle Monitoring System.

13.03.02. Diagnostics

A. All IP addressable communications system equipment shall provide fault and diagnostic information to a laptop Portable Test Unit (PTU) using a standard web browser or software supplied by the Contractor and approved by the Authority.

13.04: HIGH DENSITY DATA RADIO (PROVISION)

13.04.01. Standards

A. Provisions for a High Density Data Radio (HDDR) compliant with IEEE STD 802.11 shall be provided to allow for future communication between each Married Pair vehicle and wayside systems.

B. The HDDR shall be connected to the network through a Vehicle Switch, described in T 24.03, Digital Networks.

13.04.02. Interference with Abutters and Security

A. The Contractor shall be responsible for ensuring that the HDDR does not interfere with abutters to the right of way or suffer interference from them in accordance with T 02.07, Vehicle Design Requirements, Electrical Interference.

B. Wireless data communications shall be encrypted and otherwise protected against intrusion.

C. The Contractor shall submit for Authority review and approval, the frequencies to be used for the HDDR and the data security and encryption measures to be provided. [CDRL 13-06]

13.04.03. Mounting and Antennas

A. Provisions for the mounting of the HDDR and its antenna shall be such easily replaceable to allow for future technology upgrades.

B. Roof mounted antennas of the type specified by the radio manufacturer shall be provided and installed. The mounting of the antennas shall be of a waterproof design. The antennas shall be connected to the radio transceivers with coaxial cables approved by the radio manufacturer and in compliance with T 18, Materials & Workmanship. Antennas shall be of a directional design concentrating transmission and reception in the longitudinal direction of the train to reduce interference with and from abutters to the right of way.

13.04.04. Federal Communications Commission (FCC) Requirements

A. The Contractor shall provide certification that the HDDR is compliant with all FCC regulations concerning the unlicensed bands for 802.11 radios.

13.05: PERFORMANCE

13.05.01. Automatic Station Identification (ASI) RFID tag reader.

A. The power of the ASI module transceiver and the location and orientation of the under car antenna shall permit reading of the transponder code with the transponder located anywhere within 2 feet of the track centerline.

B. The ASI module shall be able to read the transponder at any speed up to 50 mph.

13.05.02. Cab Speaker

A. The cab speakers shall be rated for 10 watts each and transformer matched to the speaker output of the Train Radio transceiver.

B. Cab speakers shall not have automatic ambient noise correction. Volume shall be adjustable by the Operator above a preset minimum.

13.05.03. Non-Cab Car Hostler Panel Radio Speaker

A. The Hostler Panel radio speaker shall be rated for 5 watts and transformer matched to the speaker output of the Train Radio transceiver.

13.05.04. PEI speakers and microphones.

A. PEI microphones shall have external noise reduction filters. Compression shall also be applied to the signal. The system shall permit a crew member to hear a passenger speaking at a distance of 20 inches from the PEI unit in a normal tone of voice with ambient noise levels up to 85 dBA. Total harmonic distortion through the system from microphone to cab handset shall be less than 2 percent.

B. The PEI unit shall provide ambient noise compensation for speaker output such that the crew member's voice may be heard at a minimum distance of 30 inches from the PEI unit with an ambient noise level up to 90 dBA.

13.05.05. PA System Performance

A. Overall performance of the PA system shall meet the performance requirements of IEEE STD 1477-1998 section 4.2.5 for frequency response, ambient noise level adjustment range, speaker distribution and intelligibility. The PA system shall compensate for ambient noise up to a 95 dBA output.

B. Total Harmonic Distortion shall be less than 2 percent. PA amplifiers and speakers shall be rated to provide sound levels of 95 dBA, at 5 feet 3 inches above the floor, without distortion or speakers rattling. Total harmonic distortion from microphone to speaker shall be less than 2%.

C. Equipment design shall prevent performance degradation due to extraneous noise, ground loops, circulating currents, and other interference signals.

D. Internal and external speakers shall meet the performance and dispersion angle requirements of IEEE STD 1477-1998 section 4.2.5

E. The Contractor shall provide calculations showing that the proposed PA and speaker design can meet the intelligibility requirements of IEEE STD 1477-1998 section 4.5.2 to the Authority for review and approval. [CDRL 13-07]

13.05.06. Automatic Announcements.

A. Higher priority announcements shall displace lower priority announcements which shall be repeated after the higher priority announcement is made. However, station Announcements that are cut off by a higher priority announcement shall not be repeated.

B. Announcements that exceed the length that can fit on the transverse announcement signs shall be displayed in sequential segments. The period for which each segment is shown shall be selected for readability. Visual announcements shall be displayed twice for each verbal announcement of the same message.

13.05.07. Destination Signs Performance

A. Front Destination Sign lettering shall be legible from no less than 150 feet in bright sunlight. The horizontal viewing angle shall comply with IEEE STD 1477-1998 requirements.

B. Side Destination Sign lettering shall be legible from no less than 75 feet in bright sunlight. The horizontal viewing angle shall comply with IEEE STD 1477-1998 requirements.

C. The legibility of the destination signs under all lighting conditions shall be demonstrated at the Unit Qualification Test.

D. The operational performance (ability to display all destinations, ability to automatically change destinations at the end location, etc) of the LED end and side destination signs shall be demonstrated at the System Qualification Test.

13.05.08. Transverse LED Announcement Sign

A. The LED Announcement Sign viewing angle shall be at least 140 degrees.

13.05.09. LCD Displays (OPTION)

A. LCD displays shall:

1. Have a minimum horizontal viewing angle of 120 degrees.
2. Have a minimum contrast ratio of 350 to 1.
3. Have at minimum, a maximum luminance of 28 candelas per sq-ft (300 candelas per sq-m).

13.05.10. Active Route Maps (OPTION)

A. The LED Active Route Map LED's shall be clearly visible through a 160 degree horizontal viewing angle.

B. When power is cycled off and on, the Active Route Map shall display the last route displayed before power was cycled off and on.

13.05.11. CCTV System.

A. All Passenger Compartment cameras shall have the capability to provide clear images through a wide range of lighting conditions, from operation in tunnels with 80% of the car interior lighting out of service to direct sunlight.

B. The cab camera shall compensate for changes in lighting rapidly enough that during entrance to a tunnel or exit from a tunnel, the period during which image quality suffers is less than 1 second.

13.05.12. Automatic Passenger Counting (APC) System (OPTION)

A. The APC System shall achieve greater than 95% accuracy in counting passengers, in both boarding and exiting directions.

B. The APC system shall accurately detect passengers and their direction of travel through the doorway regardless of passenger size.

C. The APC system shall accurately detect passengers and their direction of travel through the doorway in all weather conditions.

D. The APC system shall accurately detect passengers and their direction of travel through the doorway when other passengers are standing in the doorway.

13.06: TESTING

13.06.01. System Qualification Tests

A. Prior to installation on the first vehicle, all communications equipment shall be networked and tested in accordance with the integration requirements of T 16.09.03, Integration Testing, and TS24.07.02, Integration and Fault Tolerance Testing. During these tests, all communications systems shall be functionally tested and the protocols and messages used shall be verified against the Network interface and VMS interface control documents. The test procedures [CDRL 13-08] and reports [CDRL 13-09] shall be submitted to the Authority for review and approval.

13.06.02. APC Testing (OPTION)

A. The APC system shall be factory tested to prove correct detection of passengers boarding and exiting.

B. After the first trainset is conditionally accepted for revenue service the counting tallies on one car for one week shall be verified against video recordings to verify greater than 95% system accuracy for both boarding and exiting.

13.07: RELIABILITY

13.07.01. Mean Time Between Failures

A. The Mean Time Between Failures (MTBF) for all LED signs, interior and exterior shall exceed 200,000 hours.

B. Hard Drives on the NVR shall have a MTBF in excess of 3 years.

C. The MTBF for LCD displays shall be a minimum of 70,000 hours.

D. The MTBF to Mean Distance Between Component Failures (MDBCF) conversion is based on the assumptions:

1. Interior and exterior passenger information signs function 5,000 hours per year.

2. The AASCS system functions 8,000 hours per year.

3. Radio and Intercom function 8,000 hours per year.

4. Orange Line cars travel 55,000 miles per year and Red Line cars travel 70,000 miles per year.

E. The MDBCF for all communications systems together, excluding NVR's and CCTV cameras, shall exceed 52,000 miles. CCTV cameras and recorders are not included in the vehicle reliability calculations. Refer to T 02, Vehicle Design Requirements, for more detail.

13.08: MAINTAINABILITY

13.08.01. Replacement Time

A. Replacement of any printed circuit board module in the CCR enclosure shall take single repair person less than 10 minutes.

B. Replacement of any interior or exterior LED sign shall take a single repair person less than 40 minutes.

C. Replacement of an LCD display shall take a single repair person less than 30 minutes.

13.08.02. Fault Isolation

A. Using a laptop based PTU with a web browser or Contractor supplied software, maintenance personnel shall be able to trouble shoot the failure of any communications subsystem over the Digital Network to the lowest Line Replaceable Unit (LRU).

13.08.03. Maintainability Demonstration

A. The Contractor shall comply with the maintainability requirements of T 02.04, Maintainability.

13.09: SAFETY

13.09.01. Wayside Worker Warning System

A. Failure of the Wayside Worker Warning System shall be annunciated to the operator by the Vehicle Monitoring Display.

13.09.02. Trainline Network Failures

A. Failure of any portion of the Digital Networks for more than 20 seconds shall be annunciated to the operator by the Vehicle Monitoring Display.

13.09.03. Communication Failures

A. Failure of any PEI unit or any Crew Intercom unit shall be annunciated to the operator by the VMD.

13.10: COMPATIBILITY

13.10.01. Equipment Compatibility

A. All communications equipment shall be interchangeable between Red and Orange Line Vehicles, with the exception of Active Route Maps.

13.11: CDRL ITEMS REFERENCED

CDRL 13-01, “Communications Functional System Description”, (Ref: T 13.02.01.A)

CDRL 13-02, “Power Interface Compliance With IEEE STD 1477”, (Ref: T 13.02.03.I)

CDRL 13-03, “CCR Block Layout and Power Distribution”, (Ref: T 13.02.03.J)

CDRL 13-04, “Passenger Emergency Intercom Station”, (Ref: T 13.02.09.B)

CDRL 13-05, “NVR Shock Resistant Design”, (Ref: T 13.02.21.C.2)

CDRL 13-06, ”HDDR Frequencies and Data Security”, (Ref: T 13.04.02.C)

CDRL 13-07, “Public Address Amplifier and Speaker Calculations”, (Ref: T 13.05.05.E)

CDRL 13-08, “System Qualification and Functional Test Procedures”, (Ref: T 13.06.01.A)

CDRL 13-09, “System Qualification and Functional Test Reports”, (Ref: T 13.06.01.A)

13.12: REFERENCES

13.12.01. Standards Referenced

IEEE STD 1473, 2010 Standard for Communication Protocol Aboard Trains.

IEEE STD 1477-1998, IEEE Standard for Passenger Information System for Rail Transit Vehicles.

13.12.02. Technical Specification Cross References

T 02, Vehicle Design Requirements
T 05, Operators Cab
T 14, Interior & Exterior Appointments
T 16, Vehicle Monitoring System
T 18, Materials & Workmanship
T 24, Trainlines & Networks

PART T 14.00
INTERIOR & EXTERIOR APPOINTMENTS

Table of Contents

14.01: GENERAL

A. To maximize interior passenger capacity, the Red and Orange Line vehicles shall be arranged as Married Pairs that include a Cab Car and a Non-Cab Car.

B. The interior shall have a clean, open appearance, designed to maximize the free flow of passengers through the car.

C. As the specification is largely performance based, mock ups will weigh heavily in the Authority's review and acceptance of the vehicle interior/exterior design. Mock-up requirements are detailed in T 01, General Requirements.

D. The Authority is interested in vibrant, attractive color schemes and a modern interior design. A minimum of 3 interior design renderings shall be provided prior to production of mock up.

E. All non-metallic components selected for use in the design of the vehicle shall be tested in accordance with smoke, flame and toxicity requirements listed in T 18, Materials & Workmanship.

F. Interior fasteners shall be hidden from passenger sight to the maximum extent possible. All fasteners used in the construction of the vehicles shall be SI (metric) and comply with the Fastener Quality Act.

G. All components that require maintenance or testing shall be installed behind hinged access panels that utilize captive, tamper-proof fasteners. Hinges shall be retained with locking hardware, such as nylon lock nuts. Access panels that open with the Authority crew key shall open with a quarter-turn of the key. Closure of the access panel shall automatically re-engage the lock. LED lighting shall be included in the accessible enclosures and shall automatically energize when the access door is opened.

14.02: INTERIOR ARRANGEMENT

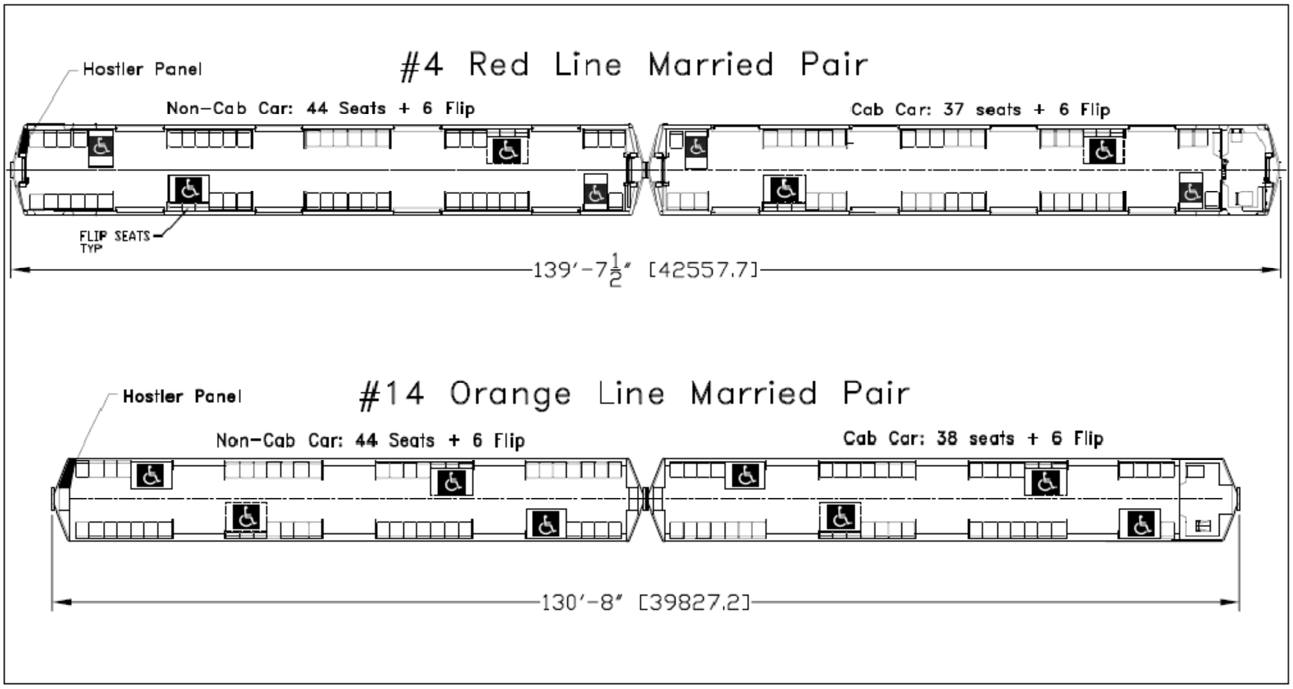

Figure 14-1 Interior Arrangement

14.02.01. Passenger Seating

A. A longitudinal layout of passenger seats is planned for the Red and Orange Line vehicles. The passenger seating shall consist of seats with the following features:

1. Fully cantilevered, stainless steel frames mounted to the vehicle sidewall. The area under the seats shall be clear of underseat boxes. The cantilever structure shall be completely hidden behind the seat back and extend no further than 3 inches below the under-side of the seat bottom.

2. Frames shall be fitted with seat inserts fabricated from a through-color material, such as a thermoplastic. Material proposed shall meet the smoke, flame and toxicity requirements of T 18, Materials & Workmanship.

3. Inserts shall be molded with curves designed for seat comfort and a texture on the surface to enhance the aesthetics and non-slip performance of the seat. Inserts shall include 19 inch wide back and bottoms secured with a tamper proof, service proven design. Proposals for insert options, including material options, finish options, attachment solutions, service history and back and bottom angle options shall be submitted for Authority review and selection. [CDRL 14-01]

4. A 1/4" (6.4 mm) through hole shall be molded into the seat bottom to allow drainage of liquids to the car floor.

B. 6 ‘flip down’ seats shall be provided per car as shown in Figure 14-1, Interior Arrangement. When not in use, the seats shall slowly revert to the vertical position (by means of a gas strut, or similar device) to provide a clear space for wheeled mobility devices.

1. The underside of flip down seats shall be fitted with a horizontal grab bar.

C. Cantilevered longitudinal seats shall be strength tested to the following:

1. 250 lbs (1112 N) shall be evenly distributed across the front edge of the seat. Load shall be applied in a vertical downward configuration. Seat, seat frame and cantilever shall not exhibit permanent deflection. If seats are supplied as multiple seating positions in a frame, loads shall be multiplied by the number of seating positions.

2. 250 lbs (1112 N) shall be evenly distributed across the top of the seat back. Load shall be applied in a horizontal direction, from front of seat to back. Seat, seat frame, cantilever and heater guard outlet shall not exhibit permanent deflection. If seats are supplied as multiple seating positions in a frame, loads shall be multiplied by the number of seating positions and distributed across the backs of the seats.

3. Fatigue loading of 35 lbs (16 kg) dropped from 12 inches (305 mm) above the seat a total of 20,000 times shall result in no permanent deflection or damage to the seat.

D. A passenger 'flip up' seat(s) shall be provided in front of the hostler panel in the Non-Cab Car. One or two seats shall flip up to provide clearance for an Operator to comfortably stand while operating the vehicle.

1. An easily accessible latch shall be provided to retain the seat(s) in the down and flipped up positions.

E. Samples of all seat types shall be provided for review and approval by the Authority before production release of the design. A minimum of 3 sample designs shall be provided. Inserts shall be those selected by the Authority. [CDRL 14-02]

F. The table below lists the minimum number of seats allowed in each type of car being procured under this contract:

Car	**Minimum # of Fixed Seats**	**Minimum # of Flip Seats**
Red Line #4 Cab Car	**37**	**6**
Red Line #4 Non-Cab Car	**44**	**6**
Orange Line #14 Cab Car	**38**	**6**
Orange Line #14 Non-Cab Car	**44**	**6**

Table 14-1 Passenger Seats per car type

G. Four accessible areas shall be located per Figure 14-1, Interior Arrangement.

H. All seats adjacent to windscreens as well as accessible areas shall be designated "Priority seating" and shall be fitted with signage in accordance with 14.02.24, Interior Graphics and Signs.

I. Additional flip down seats may be proposed to increase maximum passenger capacity. However, the maximum weight criteria as defined in 2.01.08 Weight must not be exceeded.

J. Seating layout shall be submitted to the Authority for review and approval. [CDRL 14-03]

K. Removal and replacement of seat inserts shall take no longer than 5 minutes per seat.

14.02.02. Stanchions & Hand Rails

A. The car interior shall be fitted with vertical stanchions and horizontal hand rails to accommodate standing passengers. All stanchions and hand rails shall be 1 1/4 to 1 1/2 inch (32 to 38 mm) diameter stainless steel with a satin finish. Stanchions and handrails shall be rigidly connected to the carbody structure. Samples of satin finish shall be submitted to the Authority for review and approval. [CDRL 14-04] Clearance between all stanchions/handrails and adjacent surfaces shall be a minimum of 2 inches (51 mm).

1. Vertical stanchions shall be located on the inboard edge of each windscreen as well as of the front edge of every second seat bottom. The lower connection point of these stanchions shall be the seat frame rather than the vehicle floor.

2. Vertical stanchions shall be fitted to each door post on the door side of each windscreen. Stanchions shall run from approximately 2 feet (0.6 m) above finished floor to 5 feet (1.5 m) above finished floor. Stanchions shall not impinge on the required 64 inch (1.6 m) clear door opening width.

3. Horizontal hand rails shall run above the seats, from windscreen to windscreen and intersect each of the seat stanchions mentioned in item 1 above. Hand rail centerline shall be located at a height not less than 6 feet (1.8 m) above the finished floor. Hand straps shall be provided between each vertical stanchion and spaced no more than 18 inches (457 mm) apart. Hand straps shall not exceed the limits of smoke, flame and toxicity established for fiberglass and plastics.

4. An elliptically shaped hand rail shall be installed in the center of the door vestibules, below and outside the perimeter of the transverse LED announcement sign. The rail centerline shall be a minimum of 6 feet, 8 inches (2.03 m) above the finished floor. The hand rail shall be arranged such that sign visibility is not obscured. The rail shall provide a hand hold for passengers in the direct center of the vestibule. Alternative, hand rail arrangements for the vestibule area may be proposed for Authority review and acceptance.

5. On the Red Line only - 3 Horizontal hand rails shall be installed along the centerline of the vehicle. Bars shall be arranged to run from windscreen to windscreen, terminating short of door vestibules. The hand rail centerline shall be

a minimum of 6 feet, 8 inches (2.03 m) above the finished floor and shall be fitted with spring loaded, stainless steel, rotating style hand loops. In the stowed position, the lowest edge of the loop shall be a minimum of 6 feet 7 inches (2.01 m) above the finished floor. Hand loops shall be spaced no more than 18 inches (457 mm) apart and be provided with satin finish as applied to the stanchions and hand rails.

6. All windscreens shall include a horizontal handrail installed 36 inches (914 mm) above the finished floor. The handrail shall attach to the vertical stanchion on the centerline of the windscreen stanchion and terminate on the sidewall.

    a. In the accessible areas, handrail shall turn 90 degrees and continue along the length of the sidewall in the accessible area.

B. The following load tests shall be performed on the stanchions and hand rails. All loads shall be applied normal to the surface and at the center point of the span. The loads shall not result in permanent deflection.

Item	Load to be applied (lbs)
Stanchions	350 (1557 N)
Hand Rails	350 (1557 N)
Hand Loops	300 (1335 N)
Hand Straps	200 (890 N)

Table 14-2 Hand Hold Strength Requirements

C. Stanchions, hand rails, hand loops and hand strap layout drawings shall be submitted for Authority review and approval. [CDRL 14-05]

14.02.03. Floor Panels

A. The floor panel material shall be composite construction. Plywood based flooring is not acceptable.

B. Floor panel material shall be a service proven product with at least 7 years of successful revenue service on a minimum of 100 cars. Floor panel service history shall be submitted for Authority review and approval. [CDRL 14-06]

C. Panels may be bolted or bonded to floor beams. Individual panels shall be full car width. Panels shall be laid up, edge-to-edge, to span the full length of the car, from end sill to end sill. No more than 16 panels shall be required to complete the floor.

D. All panel edges shall be fully supported on floor beams. Joints and edges shall be sealed with appropriate filler material that provides a continuous surface while allowing thermal expansion and contraction of panels.

E. The floors shall be isolated from carbody structure by continuous neoprene strips, bonding agent or similar material.

F. All threaded connections to the floor shall be fitted with threaded inserts or tapping plates that are completely encapsulated in solid material, such as phenolic resin or stainless steel. Items requiring structural attachments, such as stanchions and windscreens, shall pass through the floor panels and attach to carshell secondary structure. Through-holes shall be fitted with cosmetic escutcheon plates, or equivalent technique proposed for Authority acceptance.

G. The floor shall be leveled to provide a flat surface (within ± .060 in (±1.52 mm) over any 24 inch (610 mm) span). Height variations at panel joints shall be no greater than ± .030 in (± .76 mm).

H. Floor beam spacing and floor panel material strength shall be sufficient to withstand the following loads applied anywhere on the surface of the floor (prior to installation of the floor lining), without damage, delamination or deflection in excess of .030 inches (.76 mm):

1. A 300 lb (1335 N) load uniformly distributed over a .5 in (13 mm) x .5 in (13 mm) surface area.

2. A 600 lb (2669 N) load uniformly distributed over a 6 in (152 mm) x 6 in (152 mm) surface area.

3. An impact load resulting from a 5 lb (2.3 kg) steel ball dropped from a height of 4 feet (1.2 m).

I. Floor panel removal and replacement shall be demonstrated. Car shall be service-ready in 8 man-hours or less.

J. Panels, adhesive, sealants and leveling compounds, if used, shall meet the requirements of T 18, Materials & Workmanship.

K. See T 03, Carbody, for a description of the floor fire testing per ASTM E-119

14.02.04. Floor Lining

A. The floor lining shall provide a high coefficient of friction in both wet and dry conditions. Material, application procedure and color selection shall be subject to review and approval by the Authority. [CDRL 14-07]

B. Rubber and vinyl based lining materials shall not be proposed.

C. Seams shall be minimized in the layout of the floor liner, and shall be filled with appropriate material to provide a continuous, water-tight surface.

D. If feasible, the lining shall roll up the stainless steel cove under the sidewall heaters and butt to the underside of the heater enclosure.

1. Floor lining materials that cannot conform to item D above shall extend to the sidewall structure. The heater enclosure cove shall be mounted on top of the lining and be fully sealed to the floor lining to prevent liquids from reaching the sidewall.

E. The floor lining material and the adhesive used to bond the floor lining, if required, shall be as recommended by the lining manufacture and in accordance with the requirements of T 18, Materials & Workmanship.

F. Floor lining repair shall be demonstrated.

1. Car shall be service ready in 8 man-hours or less.
2. Repaired areas shall not be visibly or measurably detectable.
3. Replacement of lining shall not damage floor panels.

G. The floor lining shall include embedded Low Level Exit Path Marking (LLEPM) manufactured from High Performance Photo Luminescent (HPPL) material. The marking shall run down the centerline of the vehicle and across the centerline of the door portals. A horizontal stripe of material shall be applied directly inboard of all side door and end door thresholds. LLEPM shall be a minimum of 2 inches (51 mm) wide.

H. The HPPL material shall be in compliance with APTA RT-S-VIM-021-10, Standard for Emergency Signage for Rail Transit Vehicles.

I. The LLEPM shall be in compliance with APTA RT-S-VIM-022-10, Standard for Low-Location Emergency Path Marking for Rail Transit Vehicles.

14.02.05. Floor Heater Grilles

A. Convection type baseboard heater elements (without blowers) shall be housed in stainless steel enclosures located along the sidewalls of the vehicle. Enclosure design shall include a large radius cove that interfaces with the floor lining (T 14.02.04D above). The cove radius shall be sized such that the bottom side of the heater housing is located a minimum of 2 inches (51 mm) above the top of finished floor. Alternate proposals may be submitted by the Contractor for consideration by the Authority.

B. The top of the housing or a stainless steel guard shall close the gap between the top of the seat back and the sidewall lining.

C. In the accessible seating areas (4 per car), the heater enclosure shall be located and sized in such a way as to not encroach on the clear space allocated for wheeled mobility devices.

D. Brush finished stainless steel grilles shall enclose the elements while allowing sufficient convective airflow to ensure all surfaces exposed to passengers do not exceed a temperature of 125°F (52°C). Grille openings shall be sized and arranged to preclude insertion of trash into the enclosure.

E. The heater terminals shall be enclosed to protect passengers from electrically live connections.

F. Enclosures and grilles shall be safety grounded to the sidewall structure through a dedicated grounding strap.

G. Floor heaters shall be energized in both layover mode and full heating mode. Surface temperatures shall not exceed 125°F (51.7°C).

H. Grille samples of brush finish options and perforated hole patterns shall be provided for selection by the Authority. Approval of pattern or hole size shall not relieve the Contractor of compliance to heater guard surface temperature requirements. [CDRL 14-08]

14.02.06. Windscreens

A. Windscreens shall be located on each side of each doorway. Windscreens shall be designed to provide a modern, aesthetically pleasing appearance. Design drawings shall be submitted for Authority review and approval. [CDRL 14-09]

B. The upper portion of the windscreen shall be laminated safety glass or Authority reviewed and accepted scratch/vandal resistant material. The lower portion of the windscreen shall be opaque and match the interior side panel design. Material options may be proposed by the Contractor for discussion during mock up and design review.

C. The lower panel of the windscreen shall be coated to allow for easy removal of graffiti.

D. The inboard edge of windscreen shall be fitted with a stanchion. The stanchion shall terminate at the sidewall rather than the vehicle ceiling. The free gap between windscreen edge and stanchion shall be a minimum of 2 inches (51 mm).

E. Reduced width windscreens shall be provided adjacent to the accessible areas (4 per car).

F. All windscreens shall resist a 250 lb (1112 N) load applied over a 3 in x 5 in (75 mm x 125 mm) surface area at the center of the screen.

G. Windscreen stanchions shall resist a 350 lb (1557 N) force applied in any direction at the center point of the span without permanent deflection.

14.02.07. Interior Speakers

A. A minimum of eight interior speakers and protective grilles shall be provided per passenger area of each car. Speakers shall be flush mounted in the ceiling or corner hatch panels and be equally spaced down the length of the car.

B. Each speaker shall be provided with an electrical connector to allow quick removal and replacement. Speaker removal and replacement shall not require the removal of any other vehicle components. Speakers shall be installed with tamper proof fasteners.

C. Refer to T 13, Communications & Passenger Information System, for detailed requirements.

D. Speaker removal and replacement shall be demonstrated to require 10 minutes or less

14.02.08. Passenger Emergency Intercoms (PEIs)

A. Six PEIs shall be provided to allow passenger communication with the operator. One PEI shall be installed in each of the passenger end walls and one in each of the four accessible areas.

B. Activation of the PEI pushbutton shall automatically power the CCTV monitors of each active cab and display the appropriate camera view capturing the PEI, per 05.03.11, CCTV Display Screen and T 13, Communications & Passenger Information System.

C. Intercoms in accessible areas shall be flush mounted in the sidewall panel, located within the ADA accessibility range. Final location shall be determined during design review and approved at the mock-up.

D. Text describing use of PEI shall be proposed by the Contractor during design review. Text shall be in English, Spanish and Braille.

E. Refer to T 13, Communications & Passenger Information System, for detailed requirements.

F. PEI removal and replacement shall be demonstrated to require 10 minutes or less.

14.02.09. Interior Emergency Door Release

A. Each side door leaf shall be equipped with an emergency release lever. Actuation of the lever unlocks/partially opens the side door and the door summary loop.

B. The car number and door number of the actuated device shall appear on the Vehicle Monitoring System (VMS).

C. Release mechanisms and Bowden cables, if included, shall revert to a normal, ready to release position after doors are closed.

D. Release levers shall be located behind a hinged hatch panel near the door operator. Release levers are intended for use by Authority personnel only.

E. See T 06, Passenger Doors & Controls, for additional system details and performance requirements.

14.02.10. Passenger Emergency Stops

A. Each end wall shall be equipped with a Passenger Emergency Stop lever. Actuation of the lever shall initiate an irretrievable Emergency Brake application and unlock/open the respective end door.

B. The Passenger Emergency Stop may vent the Emergency Brake Pipe directly or be a fail-safe electrical device. In either case, the Brake Pipe shall completely vent.

C. There shall be two distinct actions of the Passenger Emergency Stop.

1. The lever shall be arranged to initiate the emergency brake application when it is rotated approximately 30 degrees.

2. Rotation of the lever approximately 60 degrees will release the end door latch. The lever shall not revert to the stowed position when the end door is not locked.

3. Alternate arrangements may be proposed during design review for Authority consideration.

D. The reset method of the Passenger Emergency Stop lever shall be discussed during design review.

E. Activation of the Passenger Emergency Stop shall automatically activate the PEI nearest the stop. The PEI shall be energized for two-way communication without the need for passenger or Operator input.

F. Activation of the Passenger Emergency Stop shall automatically power the CCTV monitors of each active cab and display the appropriate camera view capturing the Stop, per 05.03.11, CCTV Display Screen.

G. Emergency stop devices shall require no more than 20 lbs (89 N) of force to actuate the device and unlock the doors.

H. Release levers shall be secured with an easily replaceable frangible device.

I. Levers shall be labeled with HPPL signs and include one inch (25 mm) wide HPPL material around the perimeter of the stop lever.

J. Removal and replacement of the frangible device shall not require more than 2 minutes.

K. The car number of the actuated device shall appear on the Vehicle Monitoring System (VMS).

14.02.11. Transverse LED Announcement Signs

A. One double-sided Transverse LED Announcement Sign shall be provided and installed in-between each set of doorways in each car (three signs total for Red Line car and two signs total for Orange Line car). The sign shall be mounted to the ceiling in a transverse orientation. The Contractor shall ensure that signs are visible throughout the car yet not pose a risk of injury to passengers. Layout drawings shall be submitted for Authority review and approval. [CDRL 14-10]

B. The signs shall employ a connector for termination to carbody wiring.

C. Sign removal and replacement shall be demonstrated to require 10 minutes or less.

D. Refer to T 13, Communications & Passenger Information System, for detailed requirements.

14.02.12. Liquid Crystal Display (LCD) (OPTION)

A. 4 multi-color LCD displays on the Red Line cars and 3 on the Orange Line cars shall be provided. The displays shall be located on one door motor cover in each vestibule.

1. The displays shall be a minimum of 17 inches (432 mm) as measured diagonally, with a 16 x 9 aspect ratio.

2. The displays shall be general Authority announcements and/or advertising, to be determined during design review.

3. A protective layer of polycarbonate shall be installed over the display screens of the devices. Polycarbonate sheet shall be secure and tamper proof, but easily removable and replaceable by maintenance personnel.

4. Polycarbonate sheet shall be removed and replaced in 15 minutes or less.

5. Displays shall be housed in tamper proof enclosures and removable from inside the locked motor cover.

B. Refer to T 13, Communications & Passenger Information System, for detailed requirements of the system.

14.02.13. Light Emitting Diode (LED) Displays (OPTION)

A. LED displays shall be located on each door motor cover, adjacent to the LCD screens if used.

1. One Active Line Map shall be proposed per vestibule. The line map shall utilize LEDs for each station stop, highlighting current station and upcoming stations. The Line Map shall be a minimum 40 inches (1016 mm) wide by 10 inches (254 mm) tall.

2. Displays shall be housed in tamper proof enclosures and removable from inside the locked motor cover

B. Refer to T 13, Communications & Passenger Information System, for detailed requirements of the system.

14.02.14. Exterior LED Destination Signs

A. Two LED type matrix display destination signs, viewable from the exterior of the vehicle, shall be provided on each side of the car (four signs total).

B. Signs shall be visible through a side window or an enclosure above a side window.

C. One front LED destination sign, viewable from the exterior of the vehicle, shall be provided above the cab of the Cab Car.

D. Side destination sign removal and replacement shall require 30 minutes or less.

E. Front destination sign removal and replacement shall require 45 minutes or less.

F. A means shall be provided to clean glass in front of signs in 20 minutes or less. Alternatively, the Contractor may propose a sealed design that precludes the need for routine cleaning of the glass.

G. Refer to T 13, Communications & Passenger Information System, for detailed requirements.

14.02.15. Side and End wall Liners

A. Side and end wall liners shall be High Pressure Laminate (HPL), Fiberglass Reinforced Plastic (FRP), or other material proposed for Authority review and acceptance.

B. Liners shall be .125 to .188 inches (3 to 5 mm) thick.

C. Liners shall be flat. Waviness shall be limited to .030 in (.762 mm) over any 3 foot (.9 m) span.

D. Liners shall be installed in a way to avoid rattling, squeaking or other noise. All joints shall be covered with a vandal resistant molding strip that matches the color of the liners and hides fasteners.

E. Liners shall include window masks for all side and end windows. Masks shall be fitted with bulb seals or equivalent to close the gap between window and liner.

F. Liners shall not be painted. Gel coat, melamine or tedlar are acceptable surface treatments.

G. A 20 lb (89 N) load uniformly distributed over a .5 in (13 mm) x .5 in (13 mm) surface area applied anywhere on the surface of the panel shall not cause the panel to deflect more than 1/8 inch (3 mm). Upon removal of the load, the panel shall return to the original position without signs of damage or permanent deflection.

H. A 50 lb (222 N) load uniformly distributed over a 6 in (152 mm) x 6 in (152 mm) surface, applied anywhere on the liner, shall not cause any damage or cracking.

I. Graffiti resistance and liner surface repair shall be demonstrated on sample liners for Authority review and approval. [CDRL 14-11]

J. All liners shall be resistant to the Authority's standard cleaning solutions and methods. Further information will be furnished during design review.

K. A minimum of 6 sample liners shall be provided for review and selection by the Authority. Samples shall be finished in the material or color selected by the Authority. Samples shall be finished with gloss levels varying from 20% to 80%.

14.02.16. Electric Lockers

A. Lockers for equipment storage shall be located adjacent to the cab wall and Hostler Panel end wall, and be arranged not to protrude into passenger occupancy areas or obstruct passenger flow. Other locations may be proposed, subject to review and acceptance by the Authority.

B. Lockers shall be fabricated from melamine faced honeycomb panels, plywood panels or Fiberglass reinforced plastic (FRP) and shall blend in with the aesthetics of the vehicle interior.

C. Access to locker equipment shall be through hinged access panels that incorporate captive, quick release locks opened by the standard crew key.

1. Access to lockers may be from the cab side, passenger side, or both sides of the wall. The Authority's goal is to provide ease of access to the most commonly maintained items.

2. All equipment shall be removable and replaceable through the access covers and shall not require further dismantling of surrounding components.

D. Lockers shall be sealed to prevent the intrusion of dust or moisture into sensitive equipment.

1. If necessary, lockers may be partitioned so that heat producing equipment is allowed ventilation and sensitive equipment is protected from the environment. Ventilation, if required, shall not require the use of dedicated ventilation fans.

E. Lockers shall be grounded to carbody structure through dedicated safety ground straps.

14.02.17. Ceiling Panels

A. Ceiling panel material shall be aluminum honeycomb panels with a melamine surface treatment.

B. Ceiling panels shall not exhibit condensation formation on any surface under any conditions of interior humidity or temperature.

C. Panels shall be flat. Waviness shall be limited to .030 in (.762 mm) over any 3 foot (.9 m) span.

D. Alternate materials may be proposed for Authority review and acceptance.

14.02.18. Corner Hatches

A. Corner hatches shall provide the wall to ceiling transition piece and provide for continuous advertising card space along the face. Hatches shall be designed with integral, continuous flanges at the top and bottom of the advertising space that facilitate installation of cards without the need of fasteners or adhesives.

B. Hatches shall be designed to cover gaps between sections. Hatch edges shall be parallel, within .030 inches across the longest visible span.

C. Hatches shall be hinged to provide access to the door operators, terminal strips or other equipment housed in the ceiling area, as accepted by the Authority.

D. Hatches shall be fitted with tamper-proof captive fasteners of a type reviewed and accepted by the Authority. Alternate design approaches for this area may be proposed for Authority consideration.

E. Space shall be allocated for the installation of the LCD and LED signs detailed in T 14.02.12 and T 14.02.13. See T 13, Communications & Passenger Information System, for additional requirements. (OPTION)

F. Corner hatches shall be designed with an integrated advertising card holder that runs the entire length of the train between door motor covers.

G. All door pocket liners, the cab wall and the end walls shall incorporate advertising card frames. Frames shall be designed to accommodate the Authority's standard 21 inch (533 mm) x 22 inch (556 mm) advertising card.

H. The advertising card displays shall securely hold advertisements in place without the use of adhesives or fasteners

I. Door motor covers are detailed in T 06, Passenger Doors & Controls.

14.02.19. Air Diffuser/Lighting Fixtures

A. Two rows of continuous lighting shall be provided throughout the entire length of the passenger area.

B. Lighting fixtures and housing shall be anodized or powder coated aluminum extrusions that blend seamlessly with the ceiling panels and corner hatches.

C. Air diffusers may be integrated with lighting fixtures or provided separately, but shall be a continuous linear design that directs airflow towards the sidewalls as well as the center aisle.

D. Light lenses shall be hinged and retained to prevent improperly latched lenses from falling from the light fixture.

E. Fixtures shall be tamper proof, but shall allow quick and easy replacement of LEDs through hinged light diffusers.

F. Lighting performance and requirements are detailed in T 08, Lighting.

G. Air flow balancing requirements are addressed in T 07, Heating, Ventilation & Air Conditioning.

14.02.20. Interior Door Crew Switches

A. The two leading side doors nearest the cab (or hostler panel) shall be fitted with interior door crew switches. Actuation of the switch shall power the door controls and automatically open the door.

B. Switches shall be configured to operate using an Authority standard crew key.

C. The switch shall be momentary type and open the doors when rotated in one direction. Closing of the doors shall be initiated via rotation in the opposite direction.

D. Switches shall be located on the windscreen or adjacent door post.

E. Refer to T 06, Passenger Doors & Controls, for additional requirements.

14.02.21. Interior Door Open Pushbuttons

A. Door OPEN pushbuttons shall be provided at each door leaf and be mounted on the windscreen, stanchion or door post in each entranceway.

B. Refer to T 06, Passenger Doors & Controls, for additional requirements.

14.02.22. CCTV Cameras

A. A minimum of eight cameras shall be mounted within the interior of the passenger area of each car and be arranged to capture all doorways as well as the entire length of the car interior.

B. The lenses shall be positioned and sized to clearly capture each complete entranceway, from floor to ceiling as well as the general vicinity of each Passenger Emergency Intercom and Passenger Emergency Stop.

C. Camera location, enclosure design and field of view shall be demonstrated by the Contractor for Authority review and acceptance. [CDRL 14-12]

D. The camera will be housed in a durable, tamper proof housing enclosure that is designed and located to blend into the surrounding structure and minimally encroach on the ridership.

1. Multiple cameras may be housed in a single enclosure.

2. Access to the cameras will be through Authority crew key or alternate Contractor proposed system accepted by the Authority.

E. Enclosure lens shall be removable and replaceable in 10 minutes or less.

F. See T 13, Communications & Passenger Information Systems, for camera performance requirements, wiring details and recording device requirements.

14.02.23. Convenience Outlets

A. A Duplex-style, 120 volt convenience outlet shall be provided at each end of each car's passenger area. Outlet shall be a heavy duty, industrial style rated for 20 amps.

B. Outlets shall be housed within electric lockers or enclosed behind hinged, crew key accessible panels on interior liners.

C. Outlets shall be powered from a dedicated GFCI circuit breaker.

D. Outlet ground fault detection shall be demonstrated by the Contractor.

E. Refer to T 05.04.05 for cab convenience outlet requirements.

14.02.24. Interior Graphics and Signs

A. The Red Line #3 car and Blue Line #5 car signage, graphics and numbering scheme shall be used as a guideline for the new Red and Orange Line vehicles. Details shall be discussed during design reviews.

B. All signage shall conform to ADA requirements, including font, letter height, contrast, visibility, etc.

C. Except for interior emergency exit signage and side door identification signs, all interior lettering, numbering, labeling, etc., shall be clearly printed on .08 inch (2 mm) aluminum plate by either of the following processes:

1. Silk screen lettering covered with a clear anodized finish.

2. Photo-etching and epoxy paint.

D. Mechanical fastening technique for signs shall be subject to Authority review and acceptance.

E. Decals may be proposed for Authority consideration on a case by case basis.

F. All interior emergency exit signage and markings shall be manufactured from high quality, High Performance Photo Luminescent material (HPPL). The HPPL material shall be capable of emitting fluorescent and/or phosphorescent light at a high rate and for an extended period of time after absorption of light radiation from an external source.

1. Signage and markings shall be in accordance with APTA RT-S-VIM-022-10, Standard for Low-Location Emergency Path Marking for Rail Transit Vehicles and APTA RT-S-VIM-021-10, Standard for Emergency Signage for Rail Transit Vehicles:

a. All emergency exit and access signage systems shall enable passengers and emergency personnel to make positive visual identification of exit or access points.

b. An exit sign shall be provided at each end door and the cab door, visible from a low-location.

c. Markings along the perimeter of the door or door frame, visible from a low-location shall be provided.

d. Markings shall be provided on or around the door's operating handle.

2. All emergency signage shall be subject to Authority review and acceptance.

G. Signs shall be securely attached to the interior surfaces of the vehicle by rivets, or alternate method reviewed and accepted by the Authority.

H. Signs depicting the International Symbol for Accessibility (ISA), along with language indication priority seating for elderly/persons with disabilities, shall be located on the side wall above all seats designated for this purpose as well as the accessible areas. Priority seating includes all seats adjacent to windscreens and the seat directly adjacent to the accessible area.

1. All applicable ADA required signage shall be included.

I. The door number of each leaf shall be displayed on the adjacent windscreen or sidewall.

14.03: EXTERIOR ARRANGEMENT

14.03.01. Side Windows

A. Side windows shall be 1/4", laminated safety glass, tinted to allow 28% visible light transmission.

B. Windows shall be maximized in width and shall be at least 36 inches (914 mm) in height.

C. Window size and layout shall be submitted for Authority review and approval. [CDRL 14-13]

D. Zip type glazing strips shall be used to install and secure the windows in place. Glazing strip ends shall be vulcanized to form a continuous seal. A tamper resistant bracket or flange shall be provided to limit access to the zip strip ends. The zip-strip shall be an inherent part of the glazing strip.

E. Glazing strips shall be fabricated from neoprene, or Authority accepted alternate. A weather proof seal shall be achieved without the use of sealants.

F. Window shall be removable and replaceable from the exterior of the vehicle in 30 minutes or less.

14.03.02. Side Doors

A. Sliding pocket side doors, as detailed in T 06, Passenger Doors & Controls, shall be installed in the vehicle.

B. Door pocket arrangement shall prevent catching and pinching of passenger extremities.

C. Seals and brushes shall be incorporated around the entire perimeter of the door pocket to prevent pinch points and provide a weather proof seal around the entire perimeter of the door leaves.

D. A cushioning bumper(s) will be located inside the pocket to protect door and surrounding structure when the door is manually opened. Bumper shall be a hollow seal, or equivalent, that reduces the velocity of the door panel before it reaches a hard stop.

E. Access for adjustment of the bumper, upper door track and lower door track shall be provided.

14.03.03. Thresholds

A. Stainless steel thresholds shall be provided at all side and end doors of the vehicle.

B. The thresholds shall be designed to provide a high coefficient of friction in wet and dry conditions. Flame spray, or equivalent technique for Authority review and acceptance, shall be provided. Painted or adhered coatings shall not be allowed.

C. Side door thresholds shall:

1. Be designed to reduce and transition the gap between the top of finished floor and the station platforms, and direct rain water and melting snow to the exterior of the car.

2. Include a channel to accept the bottom of the door leaf. The channel shall be open on the bottom to allow debris to pass directly to the track bed and minimize the potential of door binding during opening and closing cycles. Refer to T 06.02.08, Door Panels, for additional information.

3. Include a path for water to drain under the car and prevent water entry into the car.

4. Be designed to reduce the gap between side door and platform, if required. Platform interface shall be subject to discussion during design reviews. If thresholds extend outside the carshell, they shall be tapered to provide a smooth transition to the carbody. Tapering shall commence outside of the 64 inch (1626 mm) clear door opening width.

5. Not used.

6. Be designed to work in conjunction with the "Gap Mitigation Device", described in T 06.02.10, Doors.

D. End door thresholds:

1. Shall provide a channel to guide the sliding pocket doors of the No. 2 end doors and hostler end door of the Non-Cab Car.

2. Cab Car No. 1 end door thresholds may include a lip no taller than 1/4" (6 mm), if necessary to provide a sealing surface for the end door.

14.03.04. No. 1 End Door (Cab Car only)

A. A heavy duty swing-in door shall be provided in the Cab Car for Operator access and passenger emergency egress.

B. The No.1 End door shall be stainless steel skins separated by stainless steel honeycomb, or similar filler material reviewed and accepted by the Authority.

C. Skins shall be fully and continuously sealed around the entire perimeter of the panel and the window so that the internal cavities are impervious to water penetration.

D. The door shall be fitted with robust components such as a full length stainless steel hinge and heavy duty cast latches that rotate to allow egress from the vehicle.

E. A weather proof seal shall be achieved around the entire perimeter of the door leaf.

F. The door shall be designed and gasketed to maintain a weather proof seal at speeds of 60 miles per hour (97 km/hr) combined with maximum rainfall and gusting winds as described in T 02, climatic conditions.

G. A heavy duty bumper/hold open device shall be installed to protect the cab interior from damage and hold the door in the open position. Manual closing shall be possible by a simple lever or a tug on the door.

H. The door shall be fitted with a magnetic switch that energizes the local vestibule light when opened.

I. The lower edge of the door shall seal against a small lip or edge on the top of the end sill. The lip shall function as a trough to channel water away from the door.

J. The door shall be designed to be manually opened from the interior and exterior of the car without the use of a key or special tool. Proposed arrangements shall be subject to Authority review and approval. [CDRL 14-14]

K. An FRA type I window shall be installed in the door at a height consistent with the windshields. The window shall be as wide as possible, but no less than 22 inches (559 mm). Installation materials and technique shall be as described in T 05.02.06, Windshield.

L. End doors shall allow a clear opening width of at least 30 inches (762 mm) when fully opened.

M. Water testing shall ensure that a weather proof seal is achieved around the entire perimeter of the doorway as described in T 20.22.04, Testing and Validation, End Wall Water Tests.

14.03.05. No. 1 End Door (Non-Cab Car only) & No. 2 End door

A. A heavy duty, sliding pocket door shall be provided at the rear of each car and at the hostler end of the Non-Cab Car.

B. Contractor shall demonstrate that the force to slide the door completely into the pocket shall not exceed 5 lbs (67 N).

C. The door shall utilize stainless steel skins separated by stainless steel honeycomb or similar filler material reviewed and accepted by the Authority.

D. Skins shall be fully and continuously sealed around the entire perimeter of the panel and the window so that the internal cavities are impervious to water penetration.

E. Water testing shall ensure that a weather proof seal is achieved around the entire perimeter of the doorway.

F. The door shall be hung on a heavy duty door track and slide on low friction, sealed for life bearings.

G. The door shall be designed and gasketed to maintain a weather proof seal with maximum rainfall and gusting winds as described in T 02, climatic conditions.

H. The door shall be designed to be manually opened from the exterior of the car without the use of a key or special tool. A crew key shall be required to open the door from the interior, unless the vehicle Passenger Emergency Stop valve is pulled.

I. The door shall be equipped with a hold-open latch that automatically engages. Disengagement shall be by a simple manual lever.

J. The door shall be fitted with a magnet switch that energizes the local vestibule light when opened.

K. Handles on inside and outside surfaces shall be heavy duty, as manufactured from JL Howard or Authority accepted equivalent. Handles shall be located to provide at least 2 inches (51 mm) of hand clearance from pocket edge when door is fully opened.

L. An FRA type II window shall be installed in the door at a height and technique consistent with the No. 1 End door in the Cab Car. The window shall be as wide as possible, but no less than 22 inches (559 mm).

M. End doors shall allow a clear opening width of at least 30 inches (762 mm) when fully opened.

N. The door pocket shall be enclosed by an interior liner, designed and finished to match the side and end wall liners. The pocket liner shall be fitted with a 1/4" (6.35 mm) laminated safety glass window of similar height as the side windows and a width no less than 22 inches (559 mm). The window shall be hinged to allow access to the door track. The window shall lock in place with the Authority crew key.

O. A cushioning bumper(s) will be located inside the pocket to protect door and surrounding structure when the door is opened. Bumper shall be a hollow seal or equivalent that reduces the velocity of the door panel before it reaches a hard stop. Access shall be provided to adjust the bumper.

14.03.06. Exterior Loop Steps

A. Two loop steps at each end door shall be provided for operator access and passenger emergency egress.

B. Steps shall be not less than 12 inches (305 mm) wide. Depth (foot clearance) of not less than 8 inches (203 mm) shall be provided.

C. Steps shall have an integral non-slip surface. Steps shall have a minimum cross-sectional area of ½ inch (13 mm) by1½ inch (38 mm). The steps shall be laterally braced and fastened with not less than 12 mm bolts or rivets.

D. Step surface shall be 13 to 16 inches (330 to 406 mm) above top of rail. Second step shall be 12 inches (305 mm) above first step.

E. Steps shall be fabricated from stainless steel and shall be bolted into carbody structure.

F. Steps shall be designed to support a minimum of 400 lbs (1780 N), applied at a 45 degree angle to both steps, one at a time. The load shall be uniformly distributed across a 3 inch (76 mm) span of the step. Load shall result in no permanent deformation.

G. The No. 1 end steps shall be illuminated with LED lights as described in T 08, Lighting.

14.03.07. Under-Car Equipment Boxes

A. All equipment boxes not covered in other sections of the technical specification shall:

1. Be fabricated from stainless steel or equivalently protected corrosion proof material, subject to review and acceptance by the Authority.

2. Include interior dielectric-type white paint as described in T 18, Materials & Workmanship.

3. Include hinged access panels with heavy duty, adjustable over-center latches and hold-open devices. More than one access panel per enclosure shall be included if necessary to maintain, remove or replace equipment. All hinges shall be located

near the top of the box to prevent un-intentional opening if the latch is not securely fastened.

4. Be fitted with weather-proof, multi-pin circular connectors. Individual wire termination through cable glands may be proposed for large, subject to Authority review and acceptance.

5. Include a retained seal around all access panels. Adhesive backed seals shall not be accepted.

6. Be safety hung in accordance with the requirements of T 03, Carbody.

7. Be grounded to carbody structure through a dedicated safety ground strap fastened to dedicated grounding points on equipment and carshell.

8. The Contractor shall demonstrate that the covers provide sufficient access for all maintenance tasks without requiring removal of the enclosure.

9. Equipment box interior shall remain dry after being subjected to a water test in accordance with T 20, Testing & Validation.

14.03.08. Exterior Grab Handles

A. Grab handles shall be provided on both sides of each end door. Handles shall be 1 inch (25 mm) to 1 1/2 inches (38 mm) in diameter and at least 2 feet (610 mm) long.

B. Handles shall be fabricated from stainless steel and shall be threaded into structural steel.

C. Grab handles shall not be positioned in such a way as to reduce the open door clearance width.

D. Handles shall be low enough to be accessible to a 5th percentile female standing on the first step.

E. Handles shall allow a 95th percentile male to easily enter between coupled cars.

F. Handles and their attachment shall be designed to support a 300 lb (1334 N) point load applied anywhere along the handle, with no permanent deformation.

G. Grab handle layout drawings shall be submitted for Authority review and approval. Drawings shall convey ease of access into the vehicle from vehicle ends. [CDRL 14-15]

14.03.09. Exterior Lighting

A. Lights shall be mounted with stainless steel fasteners that thread into stainless steel bosses or threaded tapping plates.

B. Fixtures shall be designed to be water-tight without the use of sealants or adhesives.

C. Exterior removal and replacement of any lens or light shall require no more than 15 minutes.

D. Refer to T 08, Lighting, for specific requirements.

14.03.10. Exterior Speakers

A. A minimum of six (3 per side) water-resistant exterior speakers shall be provided per car. Speakers shall be flush mounted to the carshell and equally spaced down the length of the car.

B. Speakers shall be mounted with stainless steel fasteners that thread into stainless steel bosses or threaded tapping plates.

C. Speakers shall be designed to be water-tight without the use of sealants or adhesives.

D. Each speaker shall be provided with an electrical connector to allow quick removal and replacement. Speakers shall be installed behind stainless steel perforated metal, or Authority accepted alternative.

E. Exterior fasteners, if required, shall be tamper proof.

F. Refer to T 13, Communications & Passenger Information System, for sound clarity and dBA requirements.

14.03.11. Inter-Car Barriers

A. ADA compliant barriers shall be installed on each end of each car type and be designed to prevent passengers from falling between the cars, while still allowing Authority staff to enter cars via intra-consist end doors.

B. The design of the intercar barrier shall provide for high visibility, easy detection with a long cane and improved overall safety over current designs. The barrier provided shall comply with 49 CFR 38.63.

C. Barriers shall be provided with an integrated grab handle located directly above the loop step. The grab handle shall be a minimum of 1 inch (25 mm) in diameter.

D. Barriers shall be compatible with end gates on existing Red and Orange Line cars and be designed not to bind under any track conditions, including the tightest reverse 'S' curves in the Authority's yards.

E. Barriers shall be resistant to deterioration due to weather and UV radiation.

F. Barriers shall be quiet and rattle free and shall not require lubrication.

G. Contractor shall submit drawings and models for Authority review and approval. [CDRL 14-16]. Final approval shall be granted pending review of vehicle mockup. Contractor shall demonstrate on the mockup that barriers sufficiently close the gap between ends of cars for ADA compliance while still allowing Authority staff to enter at intra-consist end doors.

14.03.12. Front and Rear Masks

A. Fiberglass-Reinforced Plastic (FRP) front and rear masks are preferred by the Authority to achieve a modern look. Alternate approaches that provide the aesthetics of FRP may be proposed for Authority review and acceptance. Industrial Designer renderings, as described in T 01, General, shall be the medium for alternate proposals.

B. Masks shall be fabricated utilizing Method #2 per T 18.24, Fiberglass-Reinforced Plastic.

C. Masks shall be layed up with threaded inserts and/or stainless steel strips at all connection points, including, but not limited to attachment to the carshell, exterior lighting attachments and windshield attachments. See T 18, Materials & Workmanship, for FRP construction requirements.

D. Front Destination sign shall be protected by laminated safety glass installed in the mask with standard neoprene glazing and zip strips, as used on all exterior windows.

E. All molds used in the manufacture of the end masks shall become the property of the Authority, as described in T 18.21, Mold Ownership.

F. Water tightness shall not require the use of sealant. Preformed gaskets shall be used and tested to ensure a weather proof seal is created before gaps are filled with UV resistant, color appropriate sealant.

G. The Contractor shall submit the design details of the masks for Authority review and approval. [CDRL 14-17]

H. The masks shall be easily removed and replaced for repair if necessary. The end mask material shall be easily repaired using standard FRP repair procedures. A list of repair materials and procedures shall be provided for Authority approval. [CDRL 14-18].

14.03.13. HVAC Units

A. HVAC units shall be installed on the roof of the car on a stainless steel pan that is a weather proof, integral part of the roof structure.

B. Flanges that mate to the underside of the HVAC unit are the only open passageways between the interior and exterior of the car. Flanges shall rest on sealing surfaces on the exterior of the unit.

C. Condensate shall be directed to drains on the roof pan and funneled through drain lines that terminate under the car and direct water to the track bed. Rain water and condensate shall not flow over the sides of the car.

D. The HVAC unit shall have an exterior contour that matches and blends with the carshell roof.

E. Units shall be installed utilizing vibration attenuating mounts, if required. Multi-pin circular plugs shall provide power to the HVAC unit. A safety ground strap shall be provided between unit frame and carbody.

F. Refer to T 07, HVAC, for specific HVAC performance requirements.

14.03.14. Antennas

A. The Cab Car and Non-Cab Car shall be equipped with a radio antenna on the roof of the car at close proximity to the cab or hostler panel area.

B. The Cab Car shall be equipped with provisions for a high density data radio antenna

C. The antenna mounting provisions per described as well as any other proposed antennas shall allow a complete antenna with pre-terminated cable connections to be installed from the vehicle exterior.

D. Removal of antennas shall not negatively impact the weather proof nature of the seal. Water tests shall be done with antenna installed, then removed.

E. Antennas are detailed in T 13, Communications & Passenger Information System.

14.03.15. Exterior Crew Switches

A. Each side doorway closest to the cab (or hostler panel) shall be provided with an exterior crew switch. Actuation of the switch shall automatically open both leaves of the door.

B. Switches shall be configured to operate with the Authority's standard crew key.

C. Switches shall be located on the vehicle sidewall, at a height and location easily reachable while standing on the platform.

D. Crew switch shall be sealed to provide a weather proof connection to the carbody.

E. Additional performance requirements are detailed in T 06, Passenger Doors & Controls.

14.03.16. Exterior Manual Door Release

A. Each side door leaf shall be equipped with an emergency release lever protected by a cross cut elastomeric cover as described in T 06, Passenger Doors & Controls. Actuation of the lever unlocks/opens the side door.

B. The car number and door number of the actuated device shall appear on the Vehicle Monitoring Display (VMD).

C. Performance requirements are detailed in T 06, Passenger Doors & Controls.

14.03.17. Exterior Graphics and Signs

A. The Red and Orange Line cars shall receive a colored stripe around the entire perimeter of the vehicle. The stripe shall be made from pressure sensitive vinyl tape as manufactured by 3M, or Authority accepted alternate. RAL (used for defining standard colors for paint and coating) numbers for Red and Orange stripes will be finalized during design reviews.

B. A "T" logo that is consistent with current Red and Orange Line vehicles will be delivered with each car (shipped loose). The logo shall be made from pressure sensitive vinyl, as manufactured by 3M, or Authority accepted alternate. Details will be finalized during the design reviews.

C. All signage shall conform to ADA requirements, including font, letter height, contrast, visibility, etc.

D. Information displayed on the car's exterior for maintenance purposes shall be printed on .08 inch aluminum plate as described in T 14.02.24, Interior Graphics and Signs.

E. The International Symbol of Accessibility shall be displayed on the exterior of the car at the side doors nearest the accessible locations (two signs per side).

F. Retro-reflective emergency access labels shall be applied immediately adjacent to all door releases. In addition to the indication of the door emergency release lever, the label shall provide instructions to open the door.

   1. A light background and dark lettering shall be used for the emergency access labels such that the luminance contrast ratio is 0.5 or lighter.

   2. Emergency access labels shall conform to APTA RT-S-VIM-021-10, Standard for Emergency Signage for Rail Transit Vehicles.

G. All cabinets and panels that contain capacitors or high voltage circuitry shall be provided with internal and external warning labels that indicate the maximum circuit voltage used in the cabinet or panel and time required to dissipate harmful voltage.

H. The car numbers, a minimum of 4 inches high, shall appear above the upper left-hand corner of the windshield at each cab end, including end with hostler panel, of a car.

I. Additional exterior graphics and labels shall be similar to the Red Line #3 car and Blue Line #5 car designs. Details shall be discussed during design reviews.

J. All signage shall be installed on clean, dry surfaces and be free of bubbles, defects, tears or scratches.

14.03.18. Exterior Door Open Pushbuttons

A. Door OPEN pushbuttons shall be provided near each door leaf and be mounted on the exterior skin of the carshell.

B. Refer to T 06, Passenger Doors & Controls, for design details and performance requirements..

14.04: SAFETY

14.04.01. Passenger Communications

A. Passenger Emergency Intercoms shall be provided to allow direct communication with the operator in the event of an emergency.

14.04.02. Passenger Egress/ Rescue Personnel Ingress

A. All doors shall include manual door releases.

B. Emergency ladders, evacuation chairs and stretchers shall be provided on-board to aid in the evacuation of mobility impaired passengers. See T 05, Operator's Cab, for detailed requirements.

C. Emergency rescue personnel can enter the vehicle through all doors without the use of keys, using the exterior emergency release.

14.04.03. Fire Safety

A. Two fire extinguishers shall be provided in all cars. Extinguishers shall be located in the cab of the Cab Car and behind a transparent window in the No. 1 end of the Non-Cab Car.

B. The floor construction shall be tested to ensure that a minimum of 30 minutes will be available for passenger emergency egress in the event of a fire under the car.

C. All interior materials used shall meet NFPA 130 requirements.

14.04.04. Blast-Worthiness

A. A collaborative study on blast-worthiness shall be held during the general arrangement design review. At the time of specification release, studies on this subject were underway at Newcastle University's NewRail research centre as well as through TTCI under contract from the TSA. [CDRL 14-19]

14.05: TESTING

14.05.01. Qualification Testing

A. Although most performance testing within T 14 shall be conducted on the pilot car in accordance with T 20, Testing & Validation, the items below require factory testing or testing on the mock up prior to vehicle installation. Qualification Test Procedures [CDRL 14-20] prior to testing and reports [CDRL 14-21] after testing shall be submitted for Authority review and approval.

14.05.02. Seat and Cantilever Tests

A. Seats and cantilever supports shall be tested in a fixture that is similar in design, strength and configuration as the sidewall supporting structure. All unique seat styles shall be tested. If seats are supplied as multiple seating positions in a frame, loads shall be multiplied by the number of seating positions.

B. These tests shall be repeated on the Pilot car, unless the Contractor can demonstrate that the fixture will accurately reflect the carshell support structure reaction to the loads.

14.05.03. Floor Panel Tests

A. A full width section of floor panel, complete with Floor lining, leveling compound and adhesive (if used) shall be used to demonstrate compliance with the specification. The floor sample shall be supported on a structure that accurately reflects the largest span seen on the carshell. The sample floor shall be a minimum of 3 feet long.

14.05.04. Floor Heater Guard Temperature Tests

A. A minimum 3 foot length of heater housing, complete with heater elements and heater guards, shall be tested to determine the maximum guard surface temperature. The back side of the housing shall be insulated to simulate the vehicle sidewall insulation. The watt density shall be equal to the maximum watt density calculated using the requirements contained in Table 7-3, Design Conditions - Heating.

B. The test shall be run with ambient temperature no less than 68°F (20°C).

1. The elements shall be energized and the steady state temperature of the grille shall be measured. The maximum guard temperature (or other component exposed to passengers) shall be located and recorded. Surface temperature shall not exceed 125°F (51.7°C).

C. This test shall be repeated during climate room testing (Ref: T 20.10).

14.05.05. Not used

14.05.06. No. 1 End door Window - FRA Testing

A. A Production end door shall be fitted with a window and production glazing strip and tested for compliance with FRA type 1 requirements.

14.05.07. No. 2 End door Window - FRA Testing

A. A Production end door shall be fitted with a window and production glazing strip and tested for compliance with FRA type 2 requirements.

14.05.08. HPPL Material Tests

A. Illumination levels shall meet APTA RT-S-VIM-021-10, section 2.4.1.

B. Charging light levels shall meet APTA RT-S-VIM-021-10, section 2.4.2.

14.05.09. Retro-reflective Material Tests

A. The retro-reflective material shall be certified by an independent test laboratory to be in conformance with ASTM E-810-03, Standard Test Method for SIA Retro-reflective Sheeting.

14.06: COMPATIBILITY

14.06.01. Component Compatibility

A. The carbody designs shall incorporate identical or interchangeable components, to the maximum extent practical.

B. Unless otherwise noted, all requirements listed in this section apply to both Red and Orange Line vehicles.

14.07: CDRL ITEMS REFERENCED

CDRL 14-01, “Seat Insert Options”, (Ref: T 14.02.01.A)

CDRL 14-02, “Sample Seats “, (Ref: T 14.02.01.E)

CDRL 14-03, “Seating Layout”, (Ref: T 14.02.01.J)

CDRL 14-04, “Sample Stanchion Finish”, (Ref: T 14.02.02.A)

CDRL 14-05, “Stanchions and Hand Rail Layout Drawings”, (Ref: T 14.02.02.B)

CDRL 14-06, “Floor Panel Service History”, (Ref: T 14.02.03.B)

CDRL 14-07, “Sample Floor Lining”, (Ref: T 14.02.04.A)

CDRL 14-08, “Heater Grille Sample”, (Ref: T 14.02.05.H)

CDRL 14-09, “Windscreen Drawings”, (Ref: T 14.02.6.A)

CDRL 14-10, “Interior Message Display Layout Drawing”, (Ref: T 14.02.11.A)

CDRL 14-11, “Side and End wall Liner Material Graffiti Resistance”, (Ref: T 14.02.15.G)

CDRL 14-12, “CCTV Camera Location, Enclosure Design, and Field of View”, (Ref: T 14.02.22.C)

CDRL 14-13, “Side Window Size and Layout Drawings”, (Ref: T 14.03.01.C)

CDRL 14-14, “No.1 End Door Latching Proposal”, (Ref: T 14.03.04.J)

CDRL 14-15, “Grab Handle Layout Drawings”, (Ref: T 14.03.08.G)

CDRL 14-16, “Inter-Car Barriers”, (Ref: T 14.03.11.G)

CDRL 14-17, “End Mask Drawings and details”, (Ref: T 14.03.12.G)

CDRL 14-18, “End Mask Repair Procedures”, (Ref: T 14.03.12.H)

CDRL 14-19, “Blast-Worthiness Proposal”, (Ref: T 14.04.04.A)

CDRL 14-20, “Qualification Test Procedures”, (Ref: T 14.05.01.A)

CDRL 14-21, “Qualification Test Reports”, (Ref: T 14.05.01.A)

14.08: REFERENCES

14.08.01. Standards Referenced

49 CFR Parts 37 and 38, Americans with Disabilities Act

49 CFR Parts 239, Passenger Equipment Safety Standards, Final Rule

APTA draft, Standard for Rail Transit Vehicle Emergency Exits

APTA RT-S-VIM-021-10, Standard for Emergency Signage for Rail Transit Vehicles

APTA RT-S-VIM-022-10, Standard for Low-Location Emergency Path Marking For Rail Transit Vehicles

APTA SS-C&S-006-98, Standard for Attachment Strength of Interior Fittings for Passenger Railroad Equipment

APTA SS-C&S-012-02, Standard for Row to Row Seating in Commuter Rail Cars

ASTM E119, Floor Fire Safety Standard

ASTM E162, Flame Spread Index

ASTM E662, Optical Smoke Density

ASTM B633, Zinc Plating Standard

BSS-7239, Boeing Toxicity Standard

NFPA 130, Standard for Fixed Guideway Transit and Passenger Rail Systems
Mil-Std 1472F, Human Engineering Design Criteria for Military Systems, Equipment and Facilities

14.08.02. Technical Specification Cross References

T 01, General

T 02, Vehicle Design Requirements
T 03, Carbody
T 05, Operator's Cab
T 06, Passenger Doors & Controls
T 07, Heating, Ventilation & Air Conditioning
T 08, Lighting
T 12, Friction Brakes & Pneumatic System
T 13, Communications & Passenger Information Systems
T 18, Materials & Workmanship
T 20, Testing & Validation
T 24, Trainlines & Networks

PART T 15.00
ATP & ASR

Table of Contents

15.01: GENERAL

15.01.01. Supplier Qualifications

A. The Contractor shall provide two microprocessor based Automatic Train Protection /Automatic Speed Regulation (ATP/ASR) units for each Married Pair.

B. The supplier of the ATP/ASR units shall have a proven record of supplying vital cab signal equipment for Transit Authorities with audio frequency, continuous coded cab signal systems in an electrified subway environment.

C. The ATP supplier shall demonstrate the ability to provide a system that will work on an analog, continuous coded cab signaling system with upgradeability to work in mixed analog and digital track circuit territories. The supplier shall submit to the Authority for review and approval, demonstrated successful operation of its equipment on both types of systems. [CDRL 15-01]

15.01.02. ATP/ASR Goals

A. The Authority intends that the new ATP/ASR system shall:

1. Meet the highest standards of vital safety.
2. Not used.
3. Reduce safe braking distances by limiting runaway acceleration.
4. Reduce preventive maintenance requirements by use of digital technology, by the minimizing of relays, and by self-test functions.
5. Reduce the need for emergency brake applications by use of brake assurance banking.
6. Have capability of being upgraded to work within a mixed territory of analog and digital track circuits.

15.01.03. System Description

A. The suppler shall provide a detailed functional system description to the Authority for review and approval. [CDRL 15-02]

15.02: SYSTEM DESCRIPTION & CONFIGURATION

15.02.01. ATP/ASR Power

A. The ATP/ASR units shall be powered from the DC Low Voltage Distribution Network. Each ATP/ASR unit shall have a separate low voltage circuit breaker and each ATP module and each ASR module shall have a separate conditioning power supply.

15.02.02. ATP/ASR Installation

A. Two ATP/ASR Units shall be provided in each married pair, one referred to as “Normal" and the other referred to as “Reserve".

1. The “Normal" ATP module shall have two physically independent speed sensor inputs

2. The “Reserve” ATP module shall have two physically independent speed sensor inputs.

3. There shall be a direct input from the cab signal antenna to both the “Normal” and the “Reserve” ATP units.

B. The Normal and Reserve ATP/ASR units shall be housed in one enclosure inside the cab of the Cab Car. Each ATP and ASR unit shall be housed in a separate card file to facilitate quick change out.

C. All external wiring shall be brought into the ATP/ASR case through multi-conductor cables and circular or rectangular multi-pin connectors. Cable connections shall be easily accessible. The number of conductors in a connector shall not exceed 28.

D. Cable connectors shall be keyed to prevent incorrect connections

E. Cable spares shall be as described in T 18.13, Materials & Workmanship, Wiring.

F. All discrete inputs and outputs (I/O) shall be optically or transformer isolated from logic voltage and from each other in accordance with FRA standards.

G. Vital functions shall be performed on separate boards from non-vital functions.

H. The modules shall be easily removable from the case for repair.

I. The ATP/ASR units shall be enclosed in a metal case. The case shall have a full width front door or doors that shall allow easy access for trouble shooting and removal of modules. The door(s) shall have a keyed lock. The key shall be unique for this application.

J. All components shall be mounted and designed to withstand the shock and vibration as described in T 02.02.15 Vehicle Design Requirements, Performance, Shock and Vibration.

K. Each ATP module shall also include a brake assurance system based on diverse, level mounted accelerometers or Authority approved vital equal.

L. The ATP module shall have the space and capability of being upgraded in the future to work in mixed territory with both frequency shift key digital track circuits and the existing analog cab signaling system described in this section.

15.02.03. Antenna Installation

A. The Contractor through the ATP/ASR supplier shall provide 2 frangible receiver coils (antennas) to mount to the truck frame pedestals on the front truck of each Cab Car. The plans for the mounting of the receiver coils shall be submitted for Authority review and approval. [CDRL 15-03]

B. Safety restraints shall be provided to support the receiver coils should the mounting system fail.

C. The receiver coils shall have a test winding through which the ATP Departure Test System can inject test signals into the ATP receiver.

D. The receiver coils shall be wired in series and their common output shall be connected via twisted shielded pair, to the receiver inputs of both the "Reserve" and "Normal" ATP modules.

E. The truck to carbody cables shall be routed as close to the center of truck rotation as possible to reduce twisting and stretching stresses. The cable shall be appropriately strain relieved.

F. Quick disconnect connectors shall be keyed to prevent mistaken connection to similar connectors.

G. Receiver cable wiring connections on the truck shall be made on terminal boards in junction boxes. Truck to carbody cabling shall have a quick disconnect connector on the carbody end only.

H. No conduits shall be used on the truck for routing receiver coil or any other ATP wiring.

I. The receiver cables must be routed in separate ATP system cables and conduits

15.02.04. Speed Sensor Installation

A. Two physically independent speed sensors not used by any other system shall be provided for the Normal ATP/ASR system. Two physically independent speed sensors not used by any other system shall be provided for the Reserve ATP/ASR system

B. Each speed sensor shall read either a special gear, mounted on the axle or motor, or may read a gear in the gear box associated with the intended axle.

C. The speed sensors shall be mounted in a manner which does not require gap adjustment.

D. Speed sensors shall be located and mounted in manner which facilitates inspection and replacement and shall be protected from debris kicked up from the track bed.

E. Speed sensor locations and mounting shall be submitted to the Authority for review and approval.[CDRL 15-04]

F. The speed sensor cables shall be flexible, shielded twisted pair cable meeting the specifications of the ATP supplier. The speed sensor cable shall be connected to the carbody through a waterproof multi-pin connector to facilitate truck removal. ATP speed sensor cabling shall be routed vertically from the truck to the carbody, as close as possible to the center of the truck to minimize flexing stress.

G. The Contractor shall provide support and stress relief to truck mounted speed sensor wiring to reduce wire breaks due to repetitive stress.

H. Speed sensor cables shall be routed in separate ATP system cables and conduits.

I. Quick disconnect connectors for speed sensor cables shall not be truck mounted. Quick disconnect connections shall be made on the car body.

J. Speed sensor quick disconnect connectors shall be keyed to prevent mistaken cross connection with similar cables.

15.02.05. ATP Module

A. The ATP Module shall be a vital microprocessor based system with fault logging and diagnostic capabilities.

B. The Normal and Reserve ATP units shall be configured with a hot standby feature so that failure of one unit or its inputs or outputs shall not interrupt train operation, so long as the other unit permits safe operation of the train.

1. Failure of an ATP unit shall not cause failover of the online ASR unit.

C. The Contractor shall submit a functional description of the Hot Standby feature to the Authority for review and approval. [CDRL 15-05]

D. The ATP module shall:

1. Vitally decode signal aspects sent by the wayside and picked up by the ATP receiver coils when the train is operating in the forward direction from the cab car only.

2. Vitally measure the speed of the car, with a diverse check using a second independent speed sensor and speed measurement circuit.

3. In a vital diverse manner determine the braking rate of the car.

4. Enforce overspeed limits.

5. Vitally enforce brake assurance rates during overspeed conditions through double break control of the Emergency Trainline.

6. Perform a continuous vital self-test to prove the system is free of failures. The self-test must be passed to hold off emergency brake application.

7. The ATP shall communicate with the ASR module and the Aspect Display Unit (ADU).

   a. The ATP shall provide the current signal aspect and mode of operation (ASR, Manual, Manual Release or Hostler) to the ASR module.

   b. The ATP shall send a request for service brake to the ASR during overspeed conditions.

   c. The ATP shall send the current mode of operation, the current aspect, the current speed and any overspeed condition to the ADU for display to the operator.

   d. The ATP shall receive requests for mode changes from the ADU or hostler panel.

E. The outputs of ATP/ASR units in vehicles other than the controlling married pair vehicle shall be vitally disabled.

15.02.06. ASR Module

A. The ASR Module shall be a microprocessor based system with fault logging and diagnostic capabilities.

B. The ASR Module shall read all the speed sensors independently of the ATP. The ASR shall select which speed sensors to regulate against in manner that minimizes conflict with the ATP units configured in hot standby.

C. The ASR Module shall read the direction request and traction request from the Master Controller or from the Inching Switch, described in T 05.03, Operator's Cab, Cab Controls.

   1. The command from the Inching Switch shall be considered valid only when the Master Controller is in full service brake position.

   2. Activation of the Inching Switch to power position shall be interpreted as a Master Controller request input for 20% of maximum power. Alternative approaches such as speed regulation to 3 mph or less may be proposed for consideration by the Authority.

   3. Activation of the Inching Switch to the coast position shall be interpreted as a Master Controller request for coast.

   4. Release of the Inching Switch shall cause the ASR module to re-apply the full service brake.

D. The ASR Module shall control the propulsion and braking trainlines defined in T 24.07, Coupling, Propulsion Control and Discrete Trainlines, in accordance with the Master Controller or Inching requests and the aspects provided by the ATP.

15.02.07. Aspect Display Unit (ADU)

A. The ADU shall be installed in the Operator's Console.

1. The location and size of the ADU shall be submitted for Authority review and approval. [CDRL 15-06]

B. The ADU shall have an LED speedometer display to show the operator the current speed of the train. Other options may be considered, but electromechanical speedometer displays are prohibited.

C. The ADU shall display the speed signal from the ATP which provides the lowest speed signal.

D. The ADU shall have a 7 segment LED display of the current signal aspect (speed code).

1. The signal aspect display shall flash at 1 cycle per second when the train speed exceeds the displayed signal aspect.

2. A separate red block LED "STOP" aspect shall be displayed for a STOP code.

E. The ADU shall have a built in audible alarm which shall sound whenever the ATP/ASR unit is in Manual or Manual Release mode and the train exceeds the current signal aspect speed limit.

F. The ADU shall have two labeled switches for mode selection:

1. A switch for selecting the "Normal" or the "Reserve" ASR unit on line.

2. The other switch shall be for selection of "Manual" or "ASR" mode.

G. The ADU shall have control switches for initiating the "Departure Tests" including the "Cycle Test" and the "Brake Test" as described in T 15.05, Operational Testing and Preventive Maintenance Testing.

H. The ADU shall have LED indications for a "Cycle Test" or a "Brake Test" in progress.

I. ADU shall have an LED indication to display the current operating status and modes:

1. Normal ATP healthy

2. Reserve ATP healthy

3. Normal ASR on line

4. Reserve ASR on line

5. Manual Mode

6. ASR Mode

7. Manual Release Mode

8. Hostler Panel Release Mode

9. Emergency Bypass

J. The ADU shall indicate an "ATP failure" when an ATP/ASR unit fails a self test.

15.02.08. Hostler Panel interface with ATP/ASR unit

A. The Hostler Panel shall provide both ATP modules with the following signals:

1. Hostler Panel keyed Active.

2. Hostler Panel Release request.

3. Control Handle in Maximum Brake Position.

4. Tractive effort, coast or braking requests proportional to the position of the Control Handle.

5. Direction.

6. Request for Normal or Reserve ASR module on line.

B. Activation of the Emergency Bypass Switch shall illuminate an Emergency Bypass indication on the Hostler Panel.

C. The selected active ASR module shall be indicated on the Hostler Panel.

15.02.09. Cab Signals and Code Rates

A. The ATP shall read the cab signal carrier from the antenna only when the Master Controller is in the “ON” and “FORWARD” position.

B. The MBTA Orange Line uses a 990 Hz cab signal carrier modulated at the following code rates:

Carrier	**Code rate**	**Aspect (speed command)**
990 Hz	3.8 Hz	STOP
990 Hz	6.6 Hz	10 mph
990 Hz	8.6 Hz	18 mph
990 Hz	10.8 Hz	25 mph
990 Hz	13.6 Hz	40 mph
990 Hz	20 .4 Hz	55 mph
990 Hz	5.0 Hz	Yard 10 (latched 10 mph code) (Note 1)

Table 15-1 Orange Line Code Rates and Aspects

Note 1: Yard 10 code once received shall permit 10 mph manual operation with no further code being received. Receipt of any other valid code nullifies the Yard 10 latch and the train proceeds with the new valid code. Placing the Master Controller reverser switch in neutral position also unlatches the Yard 10 code.

C. The MBTA Red Line uses two cab signal carriers 4550 Hz and 5525 Hz modulated at the following code rates:

Carrier	**Code Rate**	**Aspect (speed command)**
4550 Hz	1.25 Hz	STOP
5525 Hz	1.25 Hz	STOP
4550 Hz	2.0 Hz	10 mph
5525 Hz	2.0 Hz	15 mph
4550 Hz	3.0 Hz	25 mph
4550 Hz	4.5 Hz	40 mph
5525 Hz	4.5 Hz	50 mph
4550 Hz	6.83 Hz	60 mph
5525 Hz	6.83 Hz	Yard 10 (latched 10 mph code) (Note2)

Table 15-2 Red Line Carriers, Code Rates and Aspects

Note 2: Yard 10 code once received shall permit 10 mph manual operation with no further code being received. Receipt of any valid code other than a stop code nullifies the Yard 10 latch and the train proceeds with the new valid code. Placing the Master Controller reverser switch in neutral position also unlatches the Yard 10 code.

D. For both the Red Line and the Orange Line, absence of cab signal carrier or steady un-coded carrier or a carrier with an invalid code rate shall be interpreted as a 0 speed command.

E. If two valid code rates are detected, the lower speed command shall be enforced.

F. For both lines, the new ATP shall have the ability to detect and enforce an additional 5 mph aspect. The code rate used for this aspect shall be discussed and approved at design review.

15.02.10. Aspect Enforcement

A. The Overspeed Limits for each aspect shall be as described in T 15.03.05, Overspeed Limits. Violation of the Overspeed Limit shall result in an immediate brake request. Details of enforcement of the Overspeed Limit for each mode of operation shall be as described in T 15.02.12, Modes of Operation.

B. The Emergency Overspeed Limit is designed to vitally cut off runaway acceleration. Violation of the Emergency Overspeed Limit shall cause the ATP to immediately de-energize the Emergency Trainline. This shall result in an immediate shutdown of the traction inverters and application of the emergency brakes. The Emergency Overspeed Limit should be set high enough above the Overspeed Limit that a reasonably attentive operator will not violate the Emergency Overspeed Limit in normal manual operation but not higher than the speeds listed in T 15.03.06, Emergency Overspeed Limits.

C. When transitioning from a lower speed aspect to a higher one, the Emergency Overspeed Limit and the Overspeed Limit for the new aspect become effective as soon as the aspect is recognized by the ATP. When transitioning from a higher speed aspect to a lower one, the Overspeed Limit for the new code becomes effective as soon as the code is recognized. However, the Emergency Overspeed Limit for the previous code shall be enforced until the train speed drops below the new Overspeed Limit. At this point the new Emergency Overspeed Limit takes effect.

D. Brake Assurance.

1. During an overspeed condition, the ATP shall vitally monitor the braking rate of the train. If the train does not reach a preset brake assurance deceleration rate within a software-settable time period after the detection of an overspeed condition, the ATP shall vitally de-energize the Emergency Trainline.

2. To allow for discontinuous braking under low adhesion conditions and to minimize required emergency brake applications, the ATP shall apply a brake assurance banking algorithm. The brake assurance banking scheme shall insure that the cumulative brake rate over the brake application period meets or exceeds the brake assurance rate. It shall, however, allow for periods of time where the brake rate drops below the nominal brake assurance rate, so long as the cumulative rate does not fall below the brake assurance rate. The brake assurance banking concept proposed by the Contractor shall be submitted to the Authority for review and approval. [CDRL 15-07]

E. Emergency

1. The Emergency Brake Trainline shall be vitally controlled by the ATP. The ATP shall interrupt both positive and negative energy. De-energizing the Emergency Brake Trainline shall simultaneously:

a. De-energize Emergency Magnetic Valves in each car, thereby evacuating the Emergency Brake Pipe.

b. Disable control power to the traction inverter gate control outputs required for IGBT traction motor pulse generation.

c. Open all traction unit line contactors.

15.02.11. Automatic Speed Regulation

A. In Automatic Speed Regulation (ASR) mode, the ASR module shall read the position of the Master Controller.

1. If the Master Controller position is less restrictive than the level required for regulating train speed to the signal aspect, the ASR shall control the trainlines in a

manner necessary to comply with its control algorithm or the braking requests of the ATP.

2. If the Master Controller position is more restrictive than the level required for regulating the train speed to the signal aspect, the ASR will control the trainlines as directed by the Master Controller.

B. The propulsion and braking control trainlines shall be as defined in T 24.07, Coupling, Propulsion Controls and Discrete Trainlines.

15.02.12. Modes of Operation

A. Mode Selection

1. The operator shall be permitted to change modes only when the train is stopped and the master controller handle is in the full service brake position.

2. Selection of ASR mode or Manual mode shall be by a two position switch. The two position switch shall be located on the ADU panel.

3. Selection of Manual Release mode shall be by a momentary switch located in the cab away from the operator’s console. The Master Controller must also be in the full service brake position in order to activate the Manual Release mode.

4. The Hostler Release mode shall be selected when the Operator activates the Hostler Panel and selects a direction with the Hostler Panel power handle in the maximum brake position. The Master Controller must be in the Store Position.

5. Selection of the Emergency Bypass mode shall be accomplished by activation of an Emergency Bypass switch. The switch shall be located in the cab, in a locked enclosure that requires the operator to get out of his seat to reach. There shall be only one Emergency Bypass switch per Married Pair. The vehicle may be operated in Emergency Bypass mode from either the Master Controller or the Hostler Panel.

B. Automatic Speed Regulation (ASR)

1. The ATP sends the received aspect (speed codes) to the ASR

2. The ASR module limits the Master Controller traction effort and controls the trainlines to regulate speed to +0 – 3 mph of the speed code when the Master Controller request is greater than or equal to the trainline requests of the ASR.

3. The Master Controller can control speed to a lower speed but not a higher speed.

4. When the train exceeds the Overspeed Limit, the ATP shall:

a. Make a non -vital request for a 2.2 mphps service brake rate.

b. Cause the overspeed indicator on the ADU to flash until the train is underspeed.

c. De-energize the Emergency Trainline if:

(1) The brake assurance rate is not met within a software adjustable time after the detection of an overspeed condition or,

(2) At anytime during the overspeed condition the brake assurance bank is emptied.

(3) When the train exceeds the Emergency Overspeed Limit, the ATP shall de-energize the Emergency Trainline immediately unless the deceleration rate already exceeds the brake assurance rate.

5. During a downward code change, the Emergency Overspeed Limit of the previous code is enforced until the train is under the Overspeed Limit of the new code.

C. Manual Mode Operation

1. The ASR does not modify Master Controller requests for tractive or braking effort.

2. When the train exceeds the Overspeed Limit, the ATP:

a. Shall cause an audible alarm to be sounded until the train is underspeed.

b. Shall cause the overspeed indicator on the ADU to flash until the train is underspeed.

c. Shall make a request to immediately control the trainlines to implement a full service brake application.

d. Shall continue to apply full service brakes to a complete stop unless the operator acknowledges the overspeed alarm by moving the master controller to the full service position within 2.5 seconds. If the Operator acknowledges the overspeed alarm within 2.5 seconds the full service brake request may be released when the train is underspeed.

e. Shall de-energize the Emergency Trainline if the brake assurance rate is not met within a software adjustable time from the detection of an overspeed or if the brake assurance bank is emptied.

3. When the train exceeds the Emergency Overspeed Limit, the ATP shall de-energize the Emergency Trainline unless the deceleration rate already exceeds the brake assurance rate.

4. During a downward code change, the Emergency Overspeed Limit of the previous code is enforced until the train is under speed at the new code.

D. Manual Release Mode Operation.

1. Manual Release is a latched mode of operation.

a. Once this mode is initiated on the Orange Line, the ATP/ASR shall remain in Manual Release until a valid code is received from the wayside or the Master Controller reverser switch is placed in neutral.

b. Once Manual Release is initiated on the Red line, the ATP shall stay in this mode until a valid code other than a stop code is received or the Master Controller reverser switch is placed in neutral.

2. In the Manual Release mode, the ATP generates its own 10 mph Manual Release aspect and enforces it.

3. In Manual Release mode the ATP commands the ADU to indicate "Manual Release" on its display.

4. In Manual Release mode, the ATP activates a discrete output to the Radio Data interface (RDI) described in T 13.02.04, Train Radio System, to alert the Operations Control Center that the train is operating in Manual Release mode.

5. Operation is otherwise the same as in ASR mode.

6. When operating on the Orange Line in Manual Release mode in the forward direction from the cab car, the ATP/ASR shall revert to the previously selected mode of operation upon receipt of any valid code. The ATP shall then enforce the new code.

7. When operating in Manual Release in the forward direction from the cab car on the Red Line, the ATP/ASR shall revert to the previously selected mode of operation upon receipt on any valid code other than a stop code. The ATP shall then enforce the new code.

E. Hostler Release Operation

1. The Hostler Release mode of Operation is a latched mode of operation. Once the Hostler Release mode is activated it shall remain latched until the Hostler panel is keyed off. No operation from the Cab shall be possible while the Hostler Panel is active.

2. In Hostler Release mode, the ATP generates its own 10 mph aspect and enforces it. Enforcement is the same as in Automatic Speed Regulation mode.

3. In Hostler Release mode, the ATP vitally ignores all signals from the cab signal receiver coils.

4. In Hostler Release mode, the ATP commands the ADU to light up an indication of Hostler Release on its display.

5. In Hostler Release mode, the ATP shall activate a discrete output to the RDI described in T 13.02.04, Train Radio System, to alert the Operations Control Center that the train is operating in Hostler Release mode.

F. Emergency Bypass Operation.

1. ATP overspeed enforcement and Emergency Brake application ability shall be bypassed via a two-position Emergency Bypass switch located in a locked enclosure inside the cab.

2. In Emergency By Pass Mode, the ASR shall not require agreement between speed sensors nor health of two speed sensors to allow train motion and to perform speed regulation. It shall read which ever speed sensor provides the highest speed reading.

3. The active ASR shall control the trainlines to limit speed to 25 mph (software adjustable). Speedometer and aspect display shall remain functional, but overspeed indication shall not flash.

4. An alternative Emergency Bypass design where the ASR is bypassed altogether and the Master Controller directly controls the trainlines and speed is limited to 25 mph by propulsion logic is also acceptable.

5. An Emergency Bypass indication shall be activated on the ADU.

6. The normally on, External ATP Bypass Light, described in T 08.02.04, Exterior Indicators, shall be turned off in Emergency Bypass Operation.

7. Emergency Bypass mode shall activate a discrete output to the Radio Data Interface (RDI) described in T 13.02.04, Train Radio System. This action alerts the Operations Control Center that the train is operating in Emergency Bypass.

15.02.13. Normal/Reserve Operation

A. The Normal and Reserve ATP modules shall communicate with the online ASR module in a hot standby arrangement and shall control the Emergency Trainline in an approved parallel manner. A description of the operation of the Contractor's hot standby arrangement shall be submitted to the Authority for review and approval. (CDRL 15-08)

B. Transfer from Normal ASR online to Reserve ASR online shall be possible only when the Master Controller is in the Full service position and the train is stopped.

C. Transfer of the online ASR between Normal and Reserve shall be accomplished by moving the Normal/Reserve switch on the ADU to the opposite position.

D. For testing purposes, a three way switch shall be provided in the ATP/ASR case for forcing only the Normal or Reserve ATP online or to allow automatic hot standby configuration.

15.02.14. Diagnostics and Fault Logging

A. The ATP and ASR units shall perform a self-check at startup and shall continuously monitor proper operation, recording faults and shutting down in case of unsafe failures.

B. The ATP/ASR unit shall maintain a date and time stamped, first in first out fault log in non-volatile flash memory in accordance with T 16.06, Vehicle Monitoring System, Subsystem Integration.

C. Flash memory capacity shall be as described in T 16.06.

D. Fault logs shall include sufficient data to allow maintenance personnel to quickly isolate the source of the problem.

E. The ATP/ASR shall interface with the Vehicle Monitoring System (VMS) according to T 16.05. The ATP/ASR shall upload fault data and required system parameters, such as signal aspect, to the Married Pair Vehicle Monitoring Unit (VMU).

F. The ATP/ASR units shall have the capability of recording event and fault triggered snapshots as described in T 16.06 and T 16.07, Vehicle Monitoring System, Fault Management Description.

G. The Contractor shall provide software to allow the Authority's personnel to configure snapshot recording via the laptop Portable Test Unit as described in T 16.07.06, Snap Shots.

H. The Contractor shall incorporate ATP/ASR faults and fault descriptions into the Fault Management Plan described in T 16.07.

15.02.15. Network and Serial Interfaces

A. Each ATP/ASR unit shall have the necessary network interfaces to communicate with the VMS and the Event Recorder over the Monitoring and Train Control Network described in T 24, Trainlines and Networks.

B. Each ATP and ASR unit shall be PTU accessible through an industrial D coded M12 connector

C. The PTU shall be provided with software to enable reading of fault logs, running of diagnostic routines, temporary software configuration changes, and software upgrades.

Configuration and software changes may only be made when the PTU is connected through the local access port.

15.02.16. System Integration

A. The Contractor shall meet the Interface Control Documentation requirements of :

1. T 17.04, Software.

2. T 24.01, Trainlines and Networks, General.

3. T 16.07, Vehicle Monitoring System, Fault Management Description.

15.03: PERFORMANCE

15.03.01. Filter and Receiver Sensitivity

A. The ATP shall use a vital band pass filter to select the cab signal carrier from all the frequencies picked up by the antenna on the lead truck. Digital filters are preferred. The -3 db bandwidth shall be sufficiently wide to pass all code rates. The filter skirts shall be sufficiently steep to provide immunity to propulsion, Traction Power substation, train detection frequencies and their harmonics.

B. The sensitivity of the ATP receiver shall be adjustable.

1. The Orange Line ATP receiver shall be adjustable to decode signals as low as 150 milliamps at 990 Hz with new wheels, but shall be set to detect at 200 milliamps or above.

2. The Red Line ATP receiver shall be adjustable to decode signals as low as 100 milliamps at 4550 Hz and 5525 Hz with new wheels, but shall be set to detect at 150 milliamps or above.

3. The ATP receivers on both lines shall be able to decode signals as high as 6 amperes.

C. The current values given in this subsection are the rms current values observed when the test source is switched to steady carrier mode.

15.03.02. Speed Measurement

A. Neglecting wheel diameter error, the ATP shall measure speed to ± 0.1 mph accuracy from 5 mph up to 60 mph and shall detect speed as low as 0.5 mph or lower.

B. To mitigate the unsafe effects of errors in absolute wheel diameter settings, the wheel diameter settings shall be password protected. (A hardware key may be substituted for password protection). It is intended that the ATP wheel diameter settings shall be set at 27 inches and permanently left that way.

15.03.03. Overspeed and Emergency Overspeed Response Times

A. The ATP shall recognize an overspeed condition within 100 milliseconds of its occurrence and shall request a brake application within an additional 100 milliseconds.

B. The ATP shall recognize an emergency overspeed condition within 100 milliseconds of its occurrence and shall de-energize the Emergency Trainline within an additional 100 milliseconds.

C. The ATP shall de-energize the Emergency Trainline within 100 milliseconds of determining that the brake assurance delay time is up or the brake assurance bank is empty.

15.03.04. Aspect Recognition Time

A. The ATP shall recognize a new code aspect within 3 cycles of receiving the new code.

B. The previous aspect shall continue to be enforced for up to a software settable amount of time while the new code aspect is recognized.

1. For the Orange Line this previous aspect continuation time shall initially be set to 1.8 seconds.

2. For the Red Line this previous aspect continuation time shall initially be set to 2.5 seconds.

15.03.05. Overspeed Limit

A. The Overspeed Limit shall be set 1.0 mile per hour above the nominal aspect speed, not accounting for wheel diameter errors.

15.03.06. Emergency Overspeed Limit

A. The Emergency Overspeed Limit is designed to vitally cut off runaway acceleration. The Emergency Overspeed Limit should be set high enough that a reasonably attentive operator will not violate the limit in normal manual operation. The Emergency Overspeed Limits shall not be set higher than the following speeds, excluding wheel diameter error:

Aspect	**Emergency Overspeed Limit (Note 3)**
5 mph	7 mph
10 mph	13.0 mph
15 mph	18.0 mph
18 mph	21.0 mph
25 mph	28 mph
40 mph	42 mph
50 mph	53 mph
55 mph	58 mph
60 mph	63 mph

Table 15-3 Emergency Overspeed Limits

Note 3: The speeds listed assume 27 inch wheel diameter.

B. When transitioning from a lower speed aspect to a higher one, the Emergency Overspeed Limit for the new aspect becomes effective as soon as the aspect is recognized by the ATP.

C. When transitioning from a higher speed aspect to a lower one, the Emergency Overspeed Limit for the previous code shall be enforced until the train speed drops below the new Overspeed Limit. At this point the new Emergency Overspeed Limit shall take effect.

15.03.07. Brake Assurance Rate

A. The Brake Assurance rate shall initially be set at 1.6 mphps. The time delay before the Emergency Trainline is de-energized when the brake assurance rate is not met shall be 2.8 seconds with software adjustment from 2.5 seconds to 3 seconds.

15.03.08. Emergency Response Time

A. The ATP shall recognize and react to an emergency overspeed condition or system failure within 100 milliseconds and shall de-energize the output that controls the Emergency Trainline within an additional 100 milliseconds.

B. If the ATP uses a vital Emergency Trainline relay, the drop away time of the relay shall be less than 50 milliseconds.

15.03.09. Output Failure Detection Time.

A. The ATP shall recognize the failure of an output to turn off within 100 ms of the command to turnoff and shall vitally shutdown all outputs within an additional 100 ms.

15.03.10. Automatic Speed Regulation Tolerances

A. In ASR mode, with the Master controller in full power position and 27 inch wheels, the ASR shall regulate maximum speed to + 0 mph / - 3 mph of the nominal aspect speed. The + 0 mph limit shall be maintained, even on the steepest down grade of the Red Line or Orange Line.

15.03.11. Qualification Tests

A. Software and network integration tests shall be performed in accordance with:

1. T 17, Software Systems.

2. T 16.09.03, Vehicle Monitoring System, Integration Testing.

3. T 24.07.02, Trainlines & Networks, Integration and Fault Tolerance Testing

B. Factory Qualification Tests shall verify:

1. Successful decoding and enforcing of signal aspects.

2. Enforcement of the most restrictive signal aspect when receiving two more valid signal codes at the same time.

3. Immunity to electromagnetic interference levels described in T 02.07.

4. Verification of detection and correct response to false energy on all vital outputs

and checked inputs.

5. All performance parameters listed in T 15.03

6. Operation of the ATP hot standby configuration

7. All failover modes between the ATP and the ASR

8. Successful performance of departure Tests

9. Operation of calibration loop and relay testers described in T 15.05.01.

C. Brake Assurance Banking must be tested on the Pilot Car to assure that a cumulative 1.6 mphps brake rate is enforced.

D. Speed Regulation shall be proved in field and systems tests.

E. Test procedures shall be submitted to the Authority for review and approval. [CDRL 15-09]

F. Test shall be witnessed by an Authority representative and results shall be submitted to the Authority for review and approval. [CDRL 15-10]

15.04: RELIABILITY

15.04.01. Component Reliability

A. The ASR interface with the propulsion system shall have a Mean Distance Between Component Failures (MDBCF) in excess of 1,000,000 miles.

B. The ATP/ASR unit with all components including power supplies, speed sensors, and antenna coils shall have a MDBCF of 300,000 miles.

15.04.02. Relays

A. To maximize reliability and reduce preventive maintenance requirements, the use of vital and non-vital relays shall be kept to the minimum number compatible with safety.

15.05: OPERATIONAL TESTING AND PREVENTIVE MAINTENANCE TESTING

15.05.01. Periodic Testing

A. The ATP shall not require any periodic testing to ensure vital safety beyond:

1. Departure Tests

2. Calibration of the receiver sensitivity to compensate for wheel wear.

3. Tests for voltage isolation of all vital input circuits for which less restrictive failure may be undetectable to the vital checks of the system.

4. Testing of a minimum number of vital relays.

B. If the ATP system requires the use of vital relays, the Contractor shall provide 2 portable Diagnostic Test Equipment (DTE) relay testers for each line, for testing and recording the pickup and drop away currents and contact resistance of all vital relays installed in the ATP/ASR unit.

C. The Contractor shall provide 2 calibration DTE's for each line.

1. The DTE shall have the capability of injecting a coded cab signal carrier into a loop placed under the receiver coils, for the purpose of measuring receiver sensitivity to the cab signal at the various code rates.

2. The DTE shall have ability to inject a speed sensor input into the ATP to test overspeed and emergency overspeed response.

3. The DTE shall have the capability of performing non-destructive voltage isolation tests on any vital inputs whose less restrictive failure may be undetectable to the vital system checks.

D. The Contractor shall submit draft periodic test procedures to the Authority for review and approval, 30 day prior to the Preliminary Design Review. [CDRL 15-11]

15.06: MAINTAINABILITY

15.06.01. Modular Design

A. The ATP/ASR unit shall be of modular design with modules easily removed for maintenance.

B. Card file removal and replacement shall take less than 10 minutes.

C. Multi-conductor connectors to the case and modules shall be easily accessible. Access panels shall be provided.

15.06.02. LED Indications

A. The contractor shall provide labeled LED indications for the current status of all discrete inputs and outputs and the health of all serial communications.

15.06.03. Test Points

A. The Contractor shall provide test points on the front panel or front edge of the boards for reading all analog inputs and outputs, including but not limited to:

1. Propulsion and Braking Trainline outputs as defined in T 24, Trainlines and Networks.

2. Speed sensor inputs.

3. Direct unfiltered antenna input.

4. Direct unfiltered input from the antenna test winding.

B. Speed sensor cabling continuity shall be testable with standard volt and ohm meters.

15.06.04. Maintainability Demonstration

A. The Contractor and ATP supplier shall comply with maintainability requirements of T 02.04, Vehicle Design Requirements, Maintainability, and the FAI and Pilot Car Maintainability demonstrations described in that section.

15.07: SAFETY

15.07.01. Design Principles and Standards

A. The ATP design and manufacture shall be compliant with the safety principles and verification processes described in 49 CFR 236 subpart H, "Standards for Processor Based Signal and Train Control Systems", appendices B and C. The Contractor shall also comply with at least one of the accepted standards for safety analysis listed in appendix C.

B. The Contractor shall submit documentation that the safety analysis for the core ATP system, developed in accordance with the standards referred to in the preceding paragraph, has been reviewed and approved by an independent third party expert. [CDRL 15-12]

C. Control of the Emergency Trainline, Emergency Magnetic Valves and all other vital wiring outside the ATP/ASR unit shall be of a double break design.

D. Vital discrete inputs shall be of a double break design.

E. The ATP shall continuously check all vital outputs for false energy.

F. Failure of a system test or failure of an ATP output to shut off when commanded to do so shall result in system shutdown and removal of power from all outputs within in 100 milliseconds.

G. Wiring for the ATP/ASR system shall be run in separate cables and conduits from all other wiring.

15.07.02. Safe Braking Model

A. The Contractor shall have the responsibility to provide a vehicle and ATP system that meets the following worst case performance parameters of a safe braking model:

1. Worst case time for the ATP to recognize and begin enforcing a downgrade in code or loss of code for the Orange Line shall be software settable between 1.6 and 1.8 seconds, initially set at 1.8 seconds.

2. Worst case time for the ATP to recognize and begin enforcing a downgrade in code or loss of code for the Red Line shall be 2.5 seconds.

3. Overspeed limits for each speed code shall be as described in sub section T 15.03.05, Overspeed Limits.

4. Emergency Overspeed Limits for each speed code shall be as described in sub-section T 15.03.06, Emergency Overspeed Limits.

5. Vital speed detection shall be accurate to ± 0.1 mph from 5 mph up to 60 mph, neglecting wheel diameter errors.

6. The ATP Brake Assurance accelerometer shall be accurate to ± 0.1 mphps after proper leveling at installation.

7. The maximum time allowed for failure to meet a minimum Bake Assurance Rate before the Emergency Train Line is de-energized shall be software adjustable from 2.5 to 2.8 seconds after code change recognition.

8. Within 0.15 seconds of the request by the ATP to de-energize the Emergency Trainline, the gates on all Traction Inverters shall be shutdown.

9. Emergency brake pressure build up time shall be as described in T 02.02 Vehicle Design Requirements, Performance.

B. The Contractor shall calculate safe braking distances based on signal control lines, the brake rates used in the signal block design, and the grade and curve data provided by the Authority. The Contractor shall submit to the Authority for review and approval, the safe braking distances and buffers for all signal blocks on the Red and Orange Lines. [CDRL 15-13]

   1. The Safe Braking Model to be used for the calculations is shown in Figure 15-1 below.

C. The Authority may consider allowing slide control during emergency brake application with the Red Line or Orange Line vehicles. If this approach is taken, the Authority and the Contractor shall mutually agree upon the required changes to the Safe Braking Model. The agreement shall be based on failure mode analysis of the slide control system and the tested braking efficiency of that system.

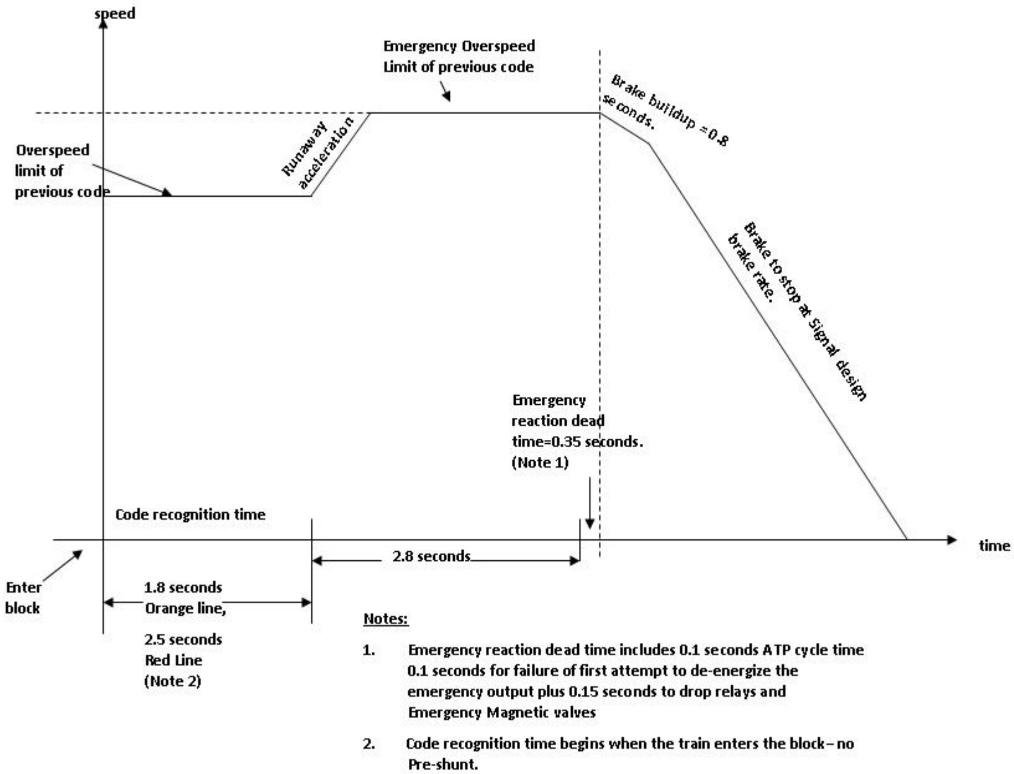

Figure 15-1 Safe Braking Model

15.07.03. Safe Braking Testing

A. It shall be the responsibility of the Contractor and the ATP/ASR supplier to prove through factory and field testing that the vehicle meets the parameter limits described in the Safe Braking Model.

B. The Contractor shall submit the test results to the Authority for review and approval. [CDRL 15-14]

C. At the completion of the Pilot Train testing for each line, the Contractor shall provide a train-set of three married pairs for testing in the presence of the Massachusetts Department of Telecommunications and Energy.

1. The Orange Line testing shall include complete runs of the Orange Line, verifying the proper speed commands are detected and enforced.

2. The Red Line testing shall include complete runs of the Red Line, verifying the proper speed commands are detected and enforced.

3. The test shall also include verification of the safe braking model at 3 selected signal blocks on each line.

15.07.04. FMECAs

A. The Contractor shall provide FMECAs on the ATP and all its vital subsystems and any vital application specific features such as emergency overspeed and brake assurance banking, hostler mode and the emergency bypass circuits. [CDRL 15-15]

B. Analysis of voltage isolation shall include board trace isolation, connectors and wiring.

15.07.05. Safety Assurance Production Testing

A. Each vital I/O board and each module used on each car shall be verified for proper voltage isolation of inputs and outputs.

B. No modified or repaired boards shall be accepted without prior Authority approval.

C. All vital input/output boards, back planes and module wiring carrying vital inputs, for which less restrictive failures cannot be detected by vital system checks shall be:

1. Tested for voltage isolation.

2. Visually inspected for manufacturing quality by an independent test laboratory selected by the Authority. This inspection shall verify compliance with the manufacturing standard cited in the safety analysis.

   a. The independent test shall be repeated after any board modification or repair.

D. Point to point verification of all internal ATP wiring and wiring harnesses shall be recorded and made available to the Authority for audit as described in T 20.21 Testing and Validation, Production Tests on Component Equipment.

E. All ATP external wiring and the Emergency Trainline shall be insulation resistance tested high pot tested and the results made available to the Authority for audit as described in T 20.21, Production Tests on Component Equipment.

F. Vital break down tests shall be performed on all external vital ATP circuits after assembly into the vehicle. The results shall be recorded and made available to the Authority for audit.

G. Software installed on each unit shall be verified to be identical to the safety tested software. The Contractor shall provide an approved means for verification of software upgrades installed via the PTU.

H. Any vital relays shall be tested and tagged after the vehicle is delivered and before it is accepted for service.

15.07.06. Connection to the Event Recorder

A. The ATP shall provide information to the Event Recorder as listed in Section T 25, Event Recorder.

15.08: COMPATIBILITY

A. The cab signaling systems on the Orange and Red Lines use different carrier frequencies and code rates. The systems require different code recognition times. Therefore it is expected that the ATP/ASR units will not be as compatible as other systems. However to the maximum extent possible the ASR module components, the Brake Assurance hardware, the receiver coils and the speed sensors shall be interchangeable.

15.09: CDRL ITEMS REFERENCED

CDRL 15-01, “Supplier Qualifications”, (Ref: T 15.01.01.C)

CDRL 15-02, “System Functional Description”, (Ref: T 15.01.03.A)

CDRL 15-03, “Plans for mounting cab signal antenna coils”, (Ref: T 15.02.03.A)

CDRL 15-04, “Plans for Location and Mounting of Speed Sensors”, (Ref: T 15.02.04.E)

CDRL 15-05, “Functional Description of Hot Standby Implementation”, (Ref: T 15.02.05.C)

CDRL 15-06, “Location and Size of ADU”, (Ref: T 15.02.07.A)

CDRL 15-07, “Brake Assurance Banking Concept”, (Ref: T 15.02.10.D.2)

CDRL 15-08, “Hot Standby Description” , (Ref: T 15.02.13.A)

CDRL 15-09, “Qualification Test Procedures”, (Ref: T 15.03.11.E)

CDRL 15-10, "Qualification Test Results", (Ref: T 15.03.11.F)

CDRL 15-11, “Draft Periodic Test Procedures”, (Ref: T 15.05.02.D)

CDRL 15-12, “Independent Safety Review and Certification”, (Ref: T 15.07.01.B)

CDRL 15-13, “Safe Braking Calculations”, (Ref: T 15.07.02.B)

CDRL 15-14, “Test of Safe Braking Model Parameters”, (Ref: T 15.07.03.B)

CDRL 15-15, “FMECA's for ATP and Subsystems”, (Ref: 15.07.04.A)

15.10: REFERENCES

15.10.01. Standards Referenced

IEEE 1483-2000, "IEEE Standard for Verification of Vital Functions in Processor-Based Systems Used in Rail Transit Control".

49 CFR 236 Subpart H, "Standards for Processor Based Signal and Train Control Systems", and Appendices B and C.

15.10.02. Technical Specification Cross References

T 02, Vehicle Design Requirements
T 08, Lighting
T 13, Communications & Passenger Information System
T 16, Vehicle Monitoring System
T 18, Materials & Workmanship
T 24, Trainlines & Networks
T 25, Event Recorder

PART T 16.00
VEHICLE MONITORING SYSTEM

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16.01: VEHICLE MONITOR SYSTEM OVERVIEW

16.01.01. General

A. The Vehicle Monitor System (VMS) shall be considered as a separate vehicle subsystem. The VMS shall be a functionally integrated system. The VMS shall:

1. Collect status and failure data from vehicle subsystems and components.

2. Exchange data between Vehicle Monitoring Units (VMU) in the same train.

3. Display train configuration and status information on the Vehicle Monitoring Display (VMD) in each cab console.

4. Permit personnel to request self-tests and data logs from the VMS and the vehicles' other subsystems.

5. Store, filter and display acquired data for operator and maintenance use.

B. In addition to the requirements of this section, the VMU and VMD microprocessor systems and software shall comply with the requirements of TS 17, Software Systems.

C. The Contractor shall submit a detailed functional system description of the vehicle monitoring system to the Authority for review and approval. [CDRL 16-01]

16.02: VEHICLE MONITORING SYSTEM CONFIGURATION

16.02.01. Configuration

A. The VMU shall serve as the central processing and storage unit for each Married Pair vehicle.

B. The VMU, on each trailing vehicle, shall communicate with the VMU on the controlling vehicle at all times.

C. Any VMU in a train shall be capable of accessing data stored in any other or all other VMUs in the train without affecting normal train operation.

D. The VMU shall provide train-level information to the VMD for display.

E. The VMD shall be located in each cab. The VMD shall display system status data and faults to the operator.

16.02.02. VMU and VMD Technology & Software

A. The VMU and VMD shall use hardened standard, commonly available microprocessors and peripheral electronics of at least 32-bit architecture.

B. The VMU shall have an internal clock which continues to keep time and date while system power is on or off.

C. The VMU fault and data storage medium shall be non-volatile solid state memory such as flash memory as described in T 17.05, Software Systems, Hardware. Magnetic or optical storage on rotating drives shall not be permitted.

D. The VMU shall employ data compression and storage technology to maximize storage capacity. The VMU shall have sufficient flash memory; that flash memory life shall exceed 30 years. The VMU shall have sufficient flash memory capacity to meet the storage requirements of this section.

E. The VMU and VMD shall use an operating system designed for real-time embedded applications in accordance with the requirements of T 17.04, Software.

F. The Contractor shall provide service history data for the proposed VMD and related equipment to the Authority for review and approval. [CDRL 16-02]

G. The VMD in each cab shall have a robust pushbutton controlled user interface. Selection of any function on the display screen shall be acknowledged by a short audible sound and shall highlight the area of the screen by means such as reverse video. The VMD display shall be of a long life LED backlit design.

H. The VMD shall provide for manual adjustment of brightness.

I. The VMD display shall incorporate anti-glare technology.

J. The VMD screen shall power off in energy saving, screen saving mode when the operating cab is keyed off. The VMD screens in the operating and door control cabs shall illuminate within 5 seconds of keying on a cab or touching the control buttons. When all cabs are keyed off in a train the VMD screens shall turned off in an energy saving mode, unless a control button is activated.

K. The VMU shall communicate directly with the VMD. The Contractor shall submit any VMU-VMD interface, other than a direct Ethernet link, to the Authority for review and approval. [CDRL 16-03] The VMU-VMD interface shall be supported by redundant links.

L. The software architecture of the VMU shall employ a method to automatically detect a corrupted process, to shut down the process, recapture all memory allocated to it, reload it and start it anew, with no secondary effects, and log the failure.

M. The VMS shall be available for service within 30 seconds of power on.

N. The VMS shall not be adversely affected by sudden interruptions of power supply less than 10 milliseconds in duration.

16.03: POWER

16.03.01. General

A. Each VMU and VMD shall be powered from the DC Low Voltage Distribution Network (LVDN) and shall contain all required power conversion and power conditioning devices required for reliable performance.

B. The VMU and VMD shall receive power whenever power is available from the LVDN and as described in of T 09.08, Battery.

16.04: INSTALLATION

16.04.01. General

A. The VMU shall be installed in an easily accessible enclosure in or near the cab.

B. The VMU and VMD shall use reliable industrial grade hardware and Electronic Industries Association / Institute of Electrical and Electronics Engineers (EIA/IEEE)-certified connectors.

C. The VMD shall be mounted in the cab console in accordance with T 05.03, Cab Controls.

D. Self ventilation of the VMU and VMD shall be such that they will operate reliably without HVAC environmental control, with vehicle operating in the worst ambient conditions described in T 02.01, Vehicle Design Requirements, General.

E. External Read Only Memory (ROM) devices or other methods shall be employed to provide the VMU with all necessary address and identification information so that no configuration is required when replacing the VMU.

16.05: VMS NETWORKS

16.05.01. General

A. The VMS shall have interfaces to the Married Pair Network (MPN).

16.05.02. Network Topology of the Monitoring and Train Control Network.

A. The Vehicle Monitoring System shall collect and transmit data over the Married Pair Network described in T 24 Trainlines & Networks.

B. Each intelligent subsystem in each Married Pair shall communicate with and report faults and parameter data to the VMU over the Married Pair Network.

C. Each VMU shall broadcast locally reported faults tagged for train wide reporting to all other VMUs over the Train Network.

16.05.03. Network Coupling

A. The VMS shall utilize the Train Network train initiation and sequencing function to obtain the sequence of cars and car numbers in the train.

B. The Train Network shall execute a train makeup and car recognition function that is capable of identifying the number, sequence and orientation of each car in a train of up to twelve cars. The Train Network shall detect and report any dead cars and their location in the train, as described in T 24. Trainlines & Networks.

C. When vehicles are coupled or uncoupled, the Train Network shall automatically reconfigure itself for the new train configuration. The configuration shall identify each vehicle in the new train by its vehicle number.

D. As the VMDs update their displays to show the new train configuration, fault and event messages pertaining to disconnected vehicles shall be removed from the display.

E. Cars with inoperative VMUs shall be shown on the Operator's VMD as present but with no information or car number.

16.05.04. Married Pair Network

A. Each VMU shall have an Ethernet interface for connection to the Married Pair Network described in T 24, Trainlines & Networks. This connection shall be used for receiving fault and alarm indications from the Ethernet communications based subsystems.

B. The VMU shall be designed to be extensible, with the understanding that additions and subtractions of systems on the Married Pair Network will occur throughout the life of the vehicle. The VMU shall be configurable to add and remove systems without requiring modifications to system source code.

1. Through a defined interface, systems added via the Married Pair Network shall be capable of full integration with the VMU, including the ability of the VMU to display and log faults, exercise self tests, and receive software configuration item version numbers.

C. The definition of faults, self tests, and software configuration items shall be transmitted over the Married Pair Network from the Ethernet communications based subsystems.

16.05.05. Portable Test Unit (PTU)

A. Each VMU shall have a local access port for a laptop Portable Test Unit (PTU)

1. The local access port shall be an industrial D coded M12 connector..

B. The PTU shall have software providing maintenance personnel full access to fault logs and diagnostics. The PTU software shall also permit configuration changes and software upgrades.

C. Software upgrades and configuration changes to the VMU shall be permitted only through the local access port.

16.06: SUBSYSTEM INTEGRATION

16.06.01. General

A. The Contractor shall in accordance with T 24, Trainlines & Networks, designate a single supplier with responsibility for network integration.

B. Network interface documentation and updates shall be provided to the Authority and subsystem suppliers as described in T 24, Trainlines and Networks.

C. The Contractor shall provide an Interface Control Document as described in T 17.04, Software, for all subsystems networked with the VMS and for the VMU and VMD. The Contractor shall keep this document current and accurate through the entire vehicle design, manufacture, delivery, testing and warranty periods.

D. Each Subsystem shall comply with the Fault Management Plan described in T 16.07

16.06.02. Subsystem fault recording

A. Each intelligent subsystem shall have a self-diagnostic, fault detection and recording capability.

B. Fault data recorded shall be sufficiently detailed to allow detection of the problem to the lowest level line replaceable unit.

C. Each intelligent subsystem shall have the capability to record snapshots of relevant system parameters for an appropriate time period and at an appropriate sampling rate for selected faults when the fault snapshot attribute is enabled.

D. Snapshots may also be triggered by configured events.

E. Each intelligent subsystem connected to the Married Pair Network shall communicate with the local VMU. Each subsystem shall report all faults and snapshots for which the report attribute is enabled to the local VMU.

F. Each intelligent subsystem shall store recorded faults in nonvolatile flash memory.

1. Non-volatile memory capacity shall be sufficient to store 60 days of faults and 30 snapshots.

2. The flash memory shall be sufficiently large and shall be managed in a manner which guards against exceeding the erase/write limits within the expected life of the vehicle.

G. For certain simple systems snapshot capability and associated storage requirements may be waived with the approval of the Authority.

H. Each Subsystem shall report essential parameters to VMS as required by T 16.07.02.

16.07: FAULT MANAGEMENT DESCRIPTION

16.07.01. General

A. The Contractor shall submit for Authority review and approval a VMS Fault Management Plan. The first submittal shall be prior to the Preliminary Design Review and shall be updated and re-submitted prior to the Final Design Review. [CDRL 16-04]

B. The VMS Fault Management Plan shall include but not be limited to the following:

1. Fault listing.

2. Detailed description of each fault.

3. Detailed description of the triggering conditions for each fault, including time delays and event counts.

4. Conditions required for fault reset.

5. Detailed description of the triggering conditions for subsystem lockout, including time delays and event counts.

6. Conditions required for lockout reset.

7. Recommended fault attributes for each fault.

16.07.02. Data Rates for Recording Essential Vehicle Parameters

A. The Contractor shall ensure the VMS samples subsystem parameters at a rate and resolution appropriate for the subsystem and the specific parameter. All parameters sampled by each VMU shall be transferred upon request to any other VMU. Certain parameters such as brake status, door leaf status, and Passenger Compartment temperature shall be broadcast train wide for display on the VMDs. The Contractor shall submit a listing for each subsystem parameter that shall be sampled by the VMU to the Authority for Review and Approval. [CDRL16-05]

16.07.03. Non Fault Events

A. Events not related to any fault that could be useful in isolating a failure shall be logged.

16.07.04. Fault Attributes

A. Attributes shall be provided to permit a fault to be:

1. Logged or not

2. Trigger a snapshot

3. Transmitted train wide

4. Trigger an alarm

5. Display on the VMD

6. Have an associated snapshot transmitted to the local VMU

B. The Contractor shall provide software on the laptop computer PTUs that will enable the user to configure the attributes of faults and to enable or disable snapshots for selected faults.

C. The Contractor shall provide a recommended set of attribute settings for each subsystem. The Contractor shall submit the list of attribute settings for each system to the Authority for review and approval. [CDRL 16-06]

D. One year after the first vehicle is conditionally accepted for revenue service the Contractor shall revise and submit records of the fault attributes for all faults for all systems based on Authority recommendations. [CDRL 16-07]

16.07.05. Fault Counter

A. The VMU shall contain a fault counter to count the number of times a fault has occurred.

16.07.06. Snap Shots

A. Each microprocessor based subsystem shall have the ability to record in its data log fault or event triggered snapshots of parameters.

1. The snapshot shall be stamped with time, date, car number, subsystem name and any associated fault or event.

B. The Contractor shall implement a de-bouncing scheme for snapshot triggering to prevent multiple snapshots from being generated by the same event.

C. The snapshot data from any subsystem shall be retrievable using a PTU at the subsystem's local access port.

D. The Contractor shall provide software on the laptop PTUs that shall allow the Authority's engineers and maintenance personnel to configure for each subsystem:

1. The events or faults which trigger snapshots

2. The data which is captured

3. The amount of time which the snapshot covers

4. The sampling rate (within the limits of the system capability).

E. This same software shall also allow retrieval of the data and its display in a chart recorder mode.

F. The Contractor shall submit, for Authority review and approval, the snapshot capabilities of each subsystem. The Contractor shall also submit the design of the integrated PTU software for managing subsystem snapshots. These submittals are due prior to the first design review. [CDRL 16-08]

16.07.07. System Clock

A. The VMS shall provide the system clock. The VMS time and date shall be used by all sub-systems within a vehicle. The VMU of the lead car shall provide the master clock for the VMS. The time and date update will occur when the vehicle is first keyed on. The time shall be displayed in Eastern Time and automatically adjusted for daylight savings time. The VMS shall have the ability to synchronize to a wayside time server or shall connect to a GPS receiver to obtain an accurate time on a periodic basis.

16.07.08. Fault log

A. Each VMU shall record status and failure data received from all subsystems through the local vehicle network of the Married Pair Network. All Faults recorded by each VMU shall include the following associated information:

a. Train make up, i.e. car numbers of each of the cars in the train.

b. Subsystem.

c. Fault code and description.

d. Car number.

e. Date and time the fault first occurred and the time at which it cleared.

f. Car mileage and hours at time of failure.

B. Faults that are still active shall be tagged as such.

16.07.09. 30 Day Fault log

A. The VMU storage capacity shall be sized such that all recorded failure data including 30 snapshots that occur within a thirty day time interval may be saved in non-volatile memory in circular buffers without data overwrites. The Contractor shall submit worst case memory usage calculations to the Authority for review and approval. [CDRL 16-09]

B. It shall be possible to clear the VMU fault logs and data logs using the PTU.

16.07.10. VMS Equations

A. The VMS shall provide the capability for user configurable logic equations to provide further capability of isolating faults.

B. The functionality shall be programmed by using a user-friendly

C. The Contractor shall submit, for Authority review and Approval, the equations capabilities of the system. The Contractor shall also submit the design of the integrated PTU software for managing equations. These submittals are due prior to the first design review. [CDRL 16-10]

16.08: VEHICLE MONITORING DISPLAY SCREENS

16.08.01. General Monitor Display

A. The Vehicle Monitor Display (VMD) shall provide three primary types of screen displays: the Status screen, Operator Help screens and the Maintenance screen. The screen display size is defined in T 05, Operator's Cab.

B. The VMD shall have mechanical buttons to move a screen cursor for selecting menus and screens and for selecting and entering characters for a password.

C. The interface for screen selection shall be the same for all screens.

D. The VMD shall display train status and failure information useful to the train operator and maintenance personnel.

E. All information shall be displayed graphically, textually, or both. Data shall be displayed in the most efficient manner available.

F. The Contractor shall provide train status and failure information in an organized manner based on the needs of operating personnel who will use the information. The Contractor shall provide control buttons to allow navigation through VMD screens as necessary to obtain the required information.

16.08.02. Status Screen

A. The status screen displays shall be sufficiently large to present the information to an Operator without requiring scrolling.

B. The Status screen shall be the default screen available upon vehicle power up.

C. The Status screen shall provide:

1. A graphic of all the cars in the train including:

    a. The car number of each car

    b. A graphic display of door leaf status for each door leaf in each car

    c. The status of the brakes for each truck

    d. A graphic display of the average temperature in the passenger compartment of each car

    e. Keyed up cars

    f. Cars with door setup switch on

2. A graphical button for selection of Train Safety Self-Test

a. When selected the Train Safety Self-Test button shall request confirmation and instruct the operator to put the master controller in full service brake. A self-test of Authority reviewed and accepted essential systems will then be initiated.

3. A graphical button for calling up the Vehicle Maintenance screen

   a. Transfer to the vehicle maintenance screen shall require a password

4. A list of up to the 10 most recent faults or alarms that would affect operation of the train

5. Time of day in hours minutes and seconds appropriately adjusted for Eastern Standard Time or Eastern Daylight Time

D. Only faults, alarms or notifications that require the operator's attention shall be displayed in an effort to avoid operator distraction.

E. Faults shall be displayed with a descriptive name, date, time, car number and location.

F. New faults or alarms shall be highlighted with a flashing contrasting background.

G. A de-bounce scheme shall be used to prevent the display of repeat faults in a short period of time.

H. An alarm shall sound until a fault is acknowledged.

I. When a fault or alarm is acknowledged text shall appear to guide the operator in dealing with the fault. This text shall be displayed in the Authority's fault severity code color and provide simple instructions for Operator's actions to be taken. The screen shall also provide a button to navigate to the appropriate help screen for further instruction.

The Authority's fault severity code is listed in the table below.

Severity Code	**Interpretation**
RED	Remove from Service Immediately
ORANGE	Finish the trip
YELLOW	Finish the day
GREEN	Address at next maintenance interval

Table 16-1 Authority Fault Severity Code

J. The Contractor shall submit the Status screen, layout and content, including help messages to the Authority for review and approval [CDRL 16-11] at Preliminary Design Review and an updated version at the Final Design Review. [CDRL 16-12]

16.08.03. Help Screens

A. The Contractor shall provide VMD help screens to display specific information to help the operator to quickly isolate or cut out a sub-system or to permit restart of the vehicle after a fault occurrence. Information displayed on this screen shall enable the operating personnel to take specific action to restart or remove the vehicle from operation. Information to be displayed on the help screen shall include, but not be limited to, the following:

1. The time and date

2. Failure

3. Status

4. Operation action to be taken

B. The Contractor shall provide a graphic showing the location of pertinent cut outs, circuit breakers, reset buttons, etc. The graphic shall be supplemented by text with enough additional detail to define the corrective measures to be taken by the vehicle Operator. The Contractor shall submit the help screens to the Authority for review and approval. [CDRL 16-13]

16.08.04. Maintenance Screen

A. The Maintenance Screen shall be accessible from the Status Screen.

1. Access to the Maintenance Screen shall be password protected.

2. In the maintenance mode one fault screen shall provide a graphical display of the status for each subsystem on each vehicle of the train, one vehicle at a time and one subsystem at a time.

3. Each subsystem shall be subdivided into its major components. Color scheme identification is recommended and should be used on the maintenance screen for subsystem and subsystem component status.

B. The Contractor shall provide fault logs of all subsystems of all cars in the train on a separate fault screen. The ability to filter and sort fault logs, at least by date, by time, and by fault type, shall be provided.

C. The Maintenance screen shall also have a function to call up the version numbers of all software installed on all subsystems on the train. The maintenance person shall be able to select the desired subsystem and call up the version numbers of all units of that subsystem on the train.

D. The Contractor shall provide a screen view and a description of each screen. The description must identify the navigation path through the screen, between screens, and the function of each control and indication on each screen. Details and descriptions of all maintenance screens proposed shall be submitted to the Authority for review and approval prior to Final Design Review. [CDRL 16-14]

16.08.05. Non Operating Cab Display

A. In non operating cabs a group of menu-selectable screens shall be provided to permit access to VMU functions that do not require use of a PTU. The VMD in non operating cabs shall display the Status Screen as a default. The test and control functions shall not be available from this screen.

B. The VMD in non-operating, non-door control cabs shall be in energy saving mode unless a control button is activated.

16.09: PERFORMANCE

16.09.01. Self-Diagnostics Test

A. The VMS shall perform self-diagnostics at power-up. If a failure is detected, a failure announcement shall be displayed on the Operator's VMD. Error conditions shall include but not be limited to, out of range, timing errors, memory allocation in excess of limits, and hardware time out errors.

B. If self-diagnostics determine that a VMU is not functioning properly, it shall be isolated from the train networks.

C. Each VMU shall perform self-checks to verify proper operation of its own subsystems and of all the subsystems connected to it through its network interfaces.

D. Each intelligent subsystem shall perform self tests at power-on to assess system readiness for service. The failure results shall be transmitted to the VMUs for display on the VMDs.

16.09.02. Safety Self- Test Command

A. Selected intelligent subsystems such as the friction brakes in a train shall perform a controlled functional self-tests when the train is stopped and they are commanded by the operator to do so through the lead VMU. Each VMU in the train shall report the results to the lead VMU via the train network for display on the Status Screen. The functional self tests can only be permitted when the vehicle is stopped with the Master Controller placed in the full service brake position.

16.09.03. Integration Testing

A. As early in the program as practicable, each subsystem shall have undergone VMS integration testing at the at the Contractor's facility.

1. The subsystem's Fault Management Plan, list of subsystem parameters to be sampled by the VMU and snapshot file parameters must be submitted prior to this testing.

2. One set of the subsystem's control electronics and network interface device (prototype or production) shall be tested with a VMU (prototype or production) and a VMD (prototype, production, or simulator).

3. Each subsystem supplier shall support this effort with hardware, software and personnel familiar with the subsystem and capable of revising its software as necessary and properly documenting any such revisions. The subsystem supplier shall use a PTU and any additional test equipment needed to simulate all faults and non-fault events external to and within the subsystem control electronics, and shall provide sample snapshot files and log files for this exercise.

4. The tests shall demonstrate each subsystem's capability to perform each VMS-related function and complete compatibility with the VMS including, but not limited to:

   a. Compliance with the Interface Control Document and the Fault Management Plan

   b. Network timing

   c. Time synchronization

   d. Proper display of events and faults

   e. Ability to configure and apply fault attributes

   f. Snapshot configuration and retrieval

   g. Fault log file request and transfer

   h. Real-time sampling and reporting of subsystem parameters

5. Test results and reports shall be submitted to the Authority for review and approval. [CDRL 16-15]

16.09.04. VMS System Level Testing

A. The VMS shall be subject to performance, qualification, factory acceptance, and reliability testing per procedures generated by the Contractor and submitted to the Authority for review and approval. [CDRL 16-16]

B. A combined factory level system test shall be conducted on one complete set of VMS equipment and subsystem control units networked over Monitoring and Train Control Networks (MTCN) described in T24, Trainlines and Networks, to simulate a 6 car train prior to the VMS first article inspection This testing may combined with the network integration test described T 24. The combined factory level test shall include a Fault Management Qualification test, Capacity test, PTU operational verification test, VMS performance test and an integration test of the completed VMS. The test shall include subsystem reporting to VMU, Fault Display, PTU operation and snapshot configuration and retrieval, etc. The tests shall verify reporting within a single Married Pair as well as fault reporting, display and controls over the MTCN train bus. The test shall include verification that the VMD status, help and maintenance screens perform as specified in this section. The combined factory level test shall also verify proper display of train composition and display of "dead" cars.

The combined factory level test results shall be submitted to the Authority for review and approval. [CDRL 16-17]

C. The Contractor shall develop and conduct a functional test of an installed VMS on the Pilot Cars to verify all features and components are in compliance with the requirements of this section.

16.10: RELIABILITY

16.10.01. Operating Reliability

A. Overall VMS reliability, operating in the Red Line and Orange Line environment, shall be not less than 500,000 miles (804,672 km) Mean Distance Between Component Failures (MDBCF).

B. The VMD shall feature an extremely high reliability display with a Mean Time Between Failures (MTBF) in excess of 100,000 hours.

16.11: MAINTAINABILITY

16.11.01. General

A. The Contractor shall provide a VMU design that permits quick installation and removal as well as easy access to internal mounted devices. Terminals and terminal blocks shall be protected from the operating environment and shall be clearly marked for positive identification.

B. The VMU control shall be combined as far as practicable into a single integral control package.

C. Each Contractor provided VMU shall be compact and provide a high reliability with a low mean time for replacement.

D. The Contractor shall comply with the maintainability requirements and demonstrations of T 02.04, Vehicle Design Requirements, Maintainability.

16.12: SAFETY

16.12.01. System Self Tests

A. System Self Tests shall be performed. Test Failures shall be reported on the VMD.

16.13: COMPATIBILITY

16.13.01. VMS Equipment

A. All VMS components shall be fully interchangeable between Red Line and Orange Line vehicles.

16.14: CDRL ITEMS REFERENCED

CDRL 16-01, “VMS Functional System Description”, (Ref: T 16.01.01.C)

CDRL 16-02, “VMD Service History”, (Ref: T 16.02.02.F)

CDRL 16-03, “VMU-VMD Interface”, (Ref: T 16.02.03.K)

CDRL 16-04, “VMU Fault Management Plan”, (Ref: T 16.07.01.A)

CDRL 16-05, “Subsystem Parameters”, (Ref: T 16.07.02.A)

CDRL 16-06, “Subsystem Fault Attribute Settings”, (Ref: T 16.07.04.C)

CDRL 16-07, “Revision of Fault Attributes after One Year of Service”, (Ref: T 16.07.04.D)

CDRL 16-08, “Snapshot Capabilities”, (Ref: T 16.07.06.F)

CDRL 16-09, “VMU Memory Usage Calculations”, (Ref: T 16.07.09.A)

CDRL 16-10, “Equation Capabilities”, (Ref: T 16.07.10.C)

CDRL 16-11, “VMD Default Screen Display Layout”, (Ref: T 16.08.02.J)

CDRL 16-12, "VMD Default Screen Display Update", (Ref: T 16.08.02.J)

CDRL 16-13, “VMD Help Screen Display”, (Ref: T 16.08.03.B)

CDRL 16-14, “VMD Maintenance Screen Displays”, (Ref: T 16.08.04.D)

CDRL 16-15, “Subsystem Integration Test Reports”, (Ref: T 16.09.03.A.5)

CDRL 16-16, “VMS Combined Factory Level Test Procedures”, (Ref: T 16.09.04.A)

CDRL 16-17, “VMS Combined Factory Level Test Reports”, (Ref: T 16.09.04.B)

16.15: REFERENCES

16.15.01. Standards Referenced

None

16.15.02. Technical Specification Cross References

T 02, Vehicle Design Requirements
T 05, Operator's Cab
T 09, Power Distribution & Auxiliary Electrical Equipment
T 13, Communications & Passenger Information System
T 17, Software Systems
T 18, Materials & Workmanship
T 20, Testing & Validation
T 24, Trainlines & Networks

PART T 17.00
SOFTWARE SYSTEMS

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17.01: GENERAL

A. This section applies to all software, microprocessor based systems supplied for this project, including vehicle subsystem controls, test equipment, data analysis, fault analysis and training deliverables.

B. This section shall also apply to the programming of all programmable devices, including microprocessors, microcontrollers, Programmable Logic Devices (PLD), Application-Specific Integrated Circuits (ASIC), or Field Programmable Gate Arrays (FPGA), etc.

17.02: SOFTWARE SYSTEMS JUSTIFICATION

A. Suppliers shall submit a life cycle cost justification for each software application not explicitly required by this specification. This justification shall include, but not be limited to, a comparison between a hardware (e.g. relays, and discreet electronic) and a software based system. For this calculation, the supplier shall use an "end of life" or obsolescence of the hardware (microprocessor and associated ICs) of 10 years and Military Handbook (MIL-HDBK)-217, Ground Mobile. Based on this analysis, the Authority will approve or disapprove the use of additional software systems.

17.03: SOFTWARE SYSTEMS REQUIREMENTS

17.03.01. Software System Classification

A. Hardware and software requirements depend on the degree to which the hardware and/or software is custom-designed for or applied to this project.

1. "Commercially available" or "Commercially Off The Shelf" (COTS) hardware or software shall be readily available in the US through retail and wholesale sources and shall be subject to all requirements, except as noted in this section.

2. "Non-commercially available" hardware or software shall be developed or modified according to the requirements in this section.

17.03.02. Time and Date Processing

A. All software and hardware delivered or developed under this Contract shall be capable of handling dates in the range from 2000 to 2099. 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 as part of the Authority’s business processes. Each hardware, software, data repository or firmware’s date data interface shall support a four-digit year format.

B. The master real time clock for all subsystems that are connected to the vehicle network shall be provided by the Vehicle Monitor System (VMS). All subsystems shall synchronize to the master clock. All time displayed to the train crew, maintenance personnel, or passengers shall be adjusted to the local time and shall automatically be adjusted to daylight saving time. The start and end dates for daylight savings time for all systems shall be adjustable by the Authority via a configuration of the VMS.

17.04: SOFTWARE

A. Not used.

17.04.02. Software Development Process

A. All Non-COTS software shall be in accordance with IEEE Std 1558-2004, Standard for Software Documentation for Rail Equipment and Systems, and the requirements stated within this specification. The IEEE Std 1558 requirements shall be for a "Type 5" procurement as defined within that standard except as noted below.

17.04.03. General Features

A. 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 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. All software shall be designed to ensure that the timing requirements for safety related tasks are always met.

4. Limit all output commands to safe levels for all combinations of input conditions, to avoid equipment damage and hazards to personnel.

5. Perform system self diagnostic routines and respond promptly, safely, and predictably to detected faults. The self diagnostics shall include tests for program corruption and integrity in read/write memories such as (Electronically Erasable Programmable Read Only Memory) EEPROM and flash Programmable Read Only Memory.

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 reinitialize all affected routines and temporary data. Detection of power interruptions may be by hardware.

7. Permit thorough interrogation of all input, output, and internal conditions by internal, system level, vehicle level and external diagnostic equipment.

8. Software version numbers shall be included within the firmware code and shall be accessible via laptop Portable Test Unit (PTU), the VMS, and on the system’s display. Every change to software shall be reflected in an update to the version number. If the software includes data or parameter files which can be modified

by the suppliers or by the Authority, a modification to such files must be reflected in a change to the software version number.

B. Undocumented software features are prohibited.

17.04.04. Contractor Activities

A. The Contractor, as system and software integrator, shall be responsible for the overall quality of all software supplied as part of this contract. If the Contractor also develops software, it shall consider the team that develops software as a supplier.

B. Quality Control Plan

1. The Contractor shall develop a car level software quality control plan which defines how it will manage and oversee the software development of its suppliers. The software quality control plan may be a section within the Contractor's project quality plan. [CDRL 17-01]

C. Software Quality Audits

1. The Contractor shall conduct periodic software quality audits of all Non-COTS suppliers. The Authority reserves the right to conduct a software quality audit at any time during the software design and development phase. At a minimum the suppliers shall plan for an audit to be performed at the Final Design Review (FDR). The results of all audits shall be submitted to the Authority for review and acceptance. [CDRL 17-02] Remedial action for all open comments from any audit shall be submitted to the Authority for review within 90 days of the audit. The Authority reserves the right to attend any audit along with the Contractor. The audit shall include:

a. Configuration control audit

b. Physical, functional, and in progress audits as defined by IEEE, Std 730

c. Coding standard compliance audit

d. Unit testing, and verification and validation testing report

D. Software Testing

1. The Contractor shall witness all software verification and validation testing prior to the release of any software. The Authority reserves the right to attend these tests along with the Contractor.

E. Configuration Control

1. The Contractor shall develop a Software Configuration Control Plan (SCCP) for tracking software changes to individual cars on the Authority property until the end of the warranty period and all retrofits are complete. The SCCP shall also control software on non-car equipment such as PTU's, BTE's, and the like, and shall include a mechanism to ensure continuing compatibility between car

software and non-car software. This plan shall be submitted for review and acceptance by the Authority. [CDRL 17-03] It shall be consistent with the Contractor's approach to configuration control of hardware and require similar approvals and tests.

2. The Contractor shall maintain a database of the software version of every software item on each car and in each piece of non-car equipment. The database shall be kept current by the Contractor at all times and made available upon request. The software version status of every software item on the car shall be provided in the Car History Book. The software version status of every software item on each piece of non-car equipment shall be provided by the Contractor with the delivery of the equipment.

F. Delivery of Software

1. At the end of the warranty period and for each software release thereafter, the Contractor shall provide to the Authority on Compact Disc Read-Only Memory (CD-ROM) or Digital Video Disc (DVD), all executables, updated software documentation, updated user documentation, and a Software Version Description (SVD). [CDRL 17-04] The requirement for CD-ROM or DVD copies and documentation shall apply to every delivery of software for non-car equipment.

2. The SVD shall contain a description of problems addressed, known problems yet to be addressed, features added, requirements added or changed, design changes, changes to related software documents and evidence of document review, test plan, and test results.

17.04.05. Software Developer Documentation

A. All suppliers which develop software shall submit for the Authority's review and approval, documentation to ensure a mature software development process that has been fully verified and validated, and can be maintained in the future. [CDRL 17-05] The Authority offers two paths listed below.

1. Submit all the documentation as required by IEEE, Std 1558, for type 5 software.

Document Name	**Software type**	**PDR**	**FDR**	**New Software Releases**
Software Project Management Plan (SPMP)	All	Yes	No	No
Software Quality Assurance Plan (SQAP)	All	Yes	No	No
Software Configuration Management Plan (SCMP)	All	Yes	No	No
Software Verification and Validation Plan (SVVP)	All	Yes	No	No
Software Verification and Validation Report (SVVR)	All Non COTS	No	No	Yes
Software Requirement Specification	All Non-	Yes	Yes	Yes

Document Name	**Software type**	**PDR**	**FDR**	**New Software Releases**
(SRS)	COTS			
Interface Control Document (ICD)	All	Yes	Yes	Yes
Software Design Description (SDD)	All Non-COTS	No	No	Yes
Database Design Description (DBDD)	All	Yes	Yes	Yes
Software Requirement Traceability Matrix (SRTM)	All Non-COTS	Yes	Yes	Yes
Software Test Plan (STP)	All Non-COTS	Yes	No	No
Software Test Procedure (STPr)	All Non-COTS	No	Yes	Yes
Software Test Report (STR)	All Non-COTS	No	No	Yes
Software Version Description (SVD)	All	No	No	Yes
Software User Manual (SUM)	All Non-COTS PTU/BTE	Yes	Yes	Yes

Table 17-1

2. In order to reduce the amount of submittals, the Contractor may combine the documents by IEEE, Std 1558,for type 5 software as follows:

   a. The SPMP, SQAP, SCMP, SVVP, and STP shall be combined into one document entitled Software Development Plans (SDP). This SDP shall include all the requirements of the individual documents.

   b. The SRS, SDD, DBDD, STPr, STR, and SVVR shall be combined into one document entitled Software Documentation (SD). This SD shall include all the requirements of the individual documents. It is expected that this document would be developed as a database and would be expanded and updated as the software is developed and tested.

   c. The ICD and DBDD shall be combined into one document entitled Software Interface Document (SID). This SID shall include all the requirements of the individual documents.

   d. The SVD and SUM, if required, shall be stand alone-documents.

Document Name	**Software type**	**PDR**	**FDR**	**New Software Releases**
Software Development Plan	All	Yes	No	No
Software Documentation (SD)	All Non-COTS	Yes	Yes	Yes

Document Name	**Software type**	**PDR**	**FDR**	**New Software Releases**
Software Interface Document (SID)	All Non-COTS	Yes	Yes	Yes
Software Version Description (SVD)	All	No	No	Yes
Software User Manual (SUM)	All Non-COTS PTU/BTE	Yes	Yes	Yes

Table 17-2

B. Regardless of which path is chosen, the Contractor or software supplier shall develop the SRS based on the technical specification requirements. The SRS shall fully link to each technical requirement. The contractor shall submit an SRTM with the first release of the SRS to the Authority. The SRTM shall use the technical section reference identification numbers as defined in the technical specification as the reference to link to the software requirement. The Contractor shall update and submit an updated version of the SRTM with each document released, strictly following the software life cycle process. The Contractor and supplier shall not proceed in the software development until the SRS document is reviewed and approved by the Authority. [CDRL 17-06] The Contractor shall submit software documentation to the Authority based on the software life cycle.

C. In order for the Authority to update, modify, or replace a system on the cars at a later date, the following documents shall be marked "Non-Proprietary": ICD, DBDD, SID and SUM.

D. The Contractor shall perform a demonstration to ensure that the ICD and DBDD or SID is complete and accurate.

17.04.06. Operating Systems and Languages

A. Software may be written in a high or low-level language; however, high-level languages such as C/C++ are preferred. The language, compiler, and its implementation for the selected microprocessor system shall be commercially available in English.

B. All languages and operating systems shall have an acceptable customer base and be in widespread use. Use of commercial operating systems such as Windows™ for onboard applications is prohibited, unless approved by the Authority on a case by case basis.

C. Where approved for non-onboard applications such as PTU and BTE, software running on Windows™ shall include a Windows™ format help file to provide context sensitive help to the user of the software.

D. All compilers shall be approved by the Authority based on previous service history.

E. The suppliers shall have a software coding standard for each programming language which shall define header information, comment requirements, module size, etc., Similar to NASA C Style Guide SEL-94-003.

17.04.07. Commercial Off-the-Shelf Software

A. Some software supplied under this contract may be commercial-off-the-shelf when approved by the Authority such as operating systems supplied for PTU and BTE.

B. For Commercially Available Software, the following shall be supplied:

1. The original data storage/transfer media (CD-ROM) functional and usage details
2. All manuals
3. All licenses required for The Authority's site use

17.04.08. Software Testing

A. All system or subsystem level features and functions of software systems which implement system or subsystem-level requirements of the Technical Specification that are allocated to software shall be testable. Field testing shall use the PTU and procedures provided under this Contract.

B. For features which are only testable off the car with special equipment, all such equipment shall be supplied by the Contractor as test equipment, and become the property of the Authority. This equipment shall provide the logic, sequencing, and emulation necessary to verify that the software functions as intended. In lieu of separate equipment, appropriate test functions may be provided within the PTU.

C. The supplier shall perform unit and module interaction testing on all software components. This unit testing shall provide 100% coverage. Automatic test tools, such as Vector Cast may be used. As a minimum full branch testing, data range and boundary testing, and error trap testing shall be completed. All unit testing results shall be fully documented in a unit testing report which shall be submitted to the Authority for review and approval. [CDRL 17-07]

D. Type tests of all software systems shall verify the proper operation of all software features, including diagnostics. The type tests shall demonstrate that the system under test can successfully recognize and report all faults listed in the VMS Fault Management Plan described in T 16.07, Fault Management Description, and all other events and parameters reported to the VMS. The Contractor shall submit the results of the type tests to the Authority for review and approval. [CDRL 17-08] Where such tests may result in damage to the system hardware, the fault or event may be simulated to avoid damage to the hardware. Such testing shall be performed any time the software is changed, prior to putting it into service.

E. Software testing shall be a prerequisite to higher level testing, such as system level and vehicle level tests. Software validation test procedures must be approved by the Authority prior to the execution of the tests.

F. After the initial version of software is installed on the cars, all software revisions shall be tested by the supplier in the supplier's facilities (laboratory) in accordance with its testing processing and procedures. After successful completion of such tests, a test version of the software revision shall be placed on a limited number of cars and dynamically tested for a period of time as approved by the Authority. Only after results of the dynamic tests on a limited number of cars have been approved by the Authority shall a new software revision be applied to the fleet or any portion of the fleet.

G. Application of any software revision to any portion of the fleet at any time shall be in conformity with the approved Configuration Control Plan of this section.

17.04.09. Software Version Numbers

A. Software version numbers shall be included within the firmware code and shall be accessible via the PTU and the Vehicle Monitoring System.

17.04.10. Software Security

A. Vehicle software systems shall be secured against unauthorized access and attack, both from within the vehicle itself and from the wayside. Security requirements shall apply both when the vehicle is in revenue service and when the vehicle is out-of-service for maintenance or storage. Security measures shall be designed and implemented such that their effect on reliability, availability and basic system operation is minimized.

17.04.11. Software Update

A. It shall be possible to update all application software with the exception of approved programmable devices (E.g. ASIC, CPLD, etc.) via the PTU connected to the system directly. Any partial or interrupted software update shall automatically return the system to the previous version of software and not leave the system in an unconfigured state.

B. The time required to upload the entire software complement for a given system, including time to replace firmware embedded in FPGAs, CPLDs, etc, shall be no more than fifteen (15) minutes.

17.04.12. Transfer of Software to Replacement Devices.

A. In order to ensure the long term maintainability of programmable devices, the Authority requires that:

1. The Contractor shall provide master copies of the compiled executable for all programmable devices such as ASICS, CPLD's, FPGA's and Read Only Memory Devices.

2. The Contractor shall also provide 6 sets of the necessary equipment and software to transfer the compiled software to new devices and to verify the integrity of the copy.

B. If the requirements of part A of this subsection are not possible to meet for any programmable device, the Contractor shall provide the Authority with a sufficient number of replacement preprogrammed devices to supply the fleet for 30 years of service.

17.04.13. Software Escrow

A. The Contractor shall maintain in escrow all proprietary source code for all software used on the vehicle and the compilers, linkers, etc. used to develop it. The source code held in escrow shall be the latest version installed on the vehicles. The Contractor shall demonstrate that the source code held in escrow compiles to produce the same executive with the same CRC or checksum as installed on the vehicles. The Contractor shall provide sufficient documentation of the source code to allow the Authority to maintain it, troubleshoot it and adjust parameters.

B. The development software held in escrow shall be of the same version used to develop the software currently installed on the vehicle.

17.05: HARDWARE

17.05.01. Hardware Platform

A. All car borne and custom computer hardware shall be designed and constructed in accordance with the general electronic design principles of Section T 18.29, Electronics, and T 18.30, Electrical and Electronic Design.

B. Any computers, whether portable or not, and any microprocessor hardware shall be readily available through retail and/or wholesale outlets in the U.S.

C. The microprocessor-based systems shall be based on an established family of microprocessors in wide use in the control system industry and the rail industry. The type and availability of each microprocessor shall be included in the design review package.

D. Any use of commercially-available computer boards for on car applications must be specifically approved by the Authority on a case-by-case basis. Such approval will be based upon a technical review of the product's suitability for use in a transit rail environment, product documentation and proof that a supply will be available for the expected life of the vehicles.

17.05.02. Microprocessor Systems Shutdown

A. A special algorithm shall be provided to ensure that:

1. Computer shutdown and restart occur in a safe and predictable manner.

2. Spurious faults are not generated during shutdown or restart.

3. Stored diagnostic data is not lost during shutdown or restart.

4. Time stamp integrity is maintained on all diagnostic data through any shutdown and restart process, including immediately after restart.

17.05.03. Program and Data Storage

A. All onboard microprocessor based systems shall store software and diagnostic data in non-volatile flash memory, or EEPROMS. The use of mechanical hard drives or optical disks is prohibited for data storage on all systems, except the network video recorders.

B. All flash memory and other memory devices with a finite number of read/write cycles shall be implemented in such a way that one sector or memory location is not written to repeatedly, thus shortening the life expectancy of the device. The life expectancy of such devices as used on the vehicle shall not be less than 30 years. The memory and processor capacity shall be designed to allow program expansion without hardware modification. Expandability and capacity requirements are as follows:

1. The memory needs of the installed software, backup copy, if required, during software update and data files shall not utilize more than 50 percent of the installed memory capacity at Type Test. This requirement applies individually to each type of memory installed, whether it is EEPROM, Flash PROM, or RAM.

2. Peak processing time demands shall not be greater than 75 percent of the available processor capacity.

17.05.04. Electrical Isolation and Pre Processing

A. All processor system input and output signals shall be isolated. High voltage inputs and outputs shall be isolated external to the microcomputer card rack. Low voltage (battery and logic voltage level) inputs and outputs shall be isolated from the 37.5 Volt input power. The isolation for the outputs can be external to the microcomputer card rack. The isolation shall accomplish the following:

1. Protect and isolate the system from damage due to over-voltage, under-voltage, transients, shorts and open circuits

2. Perform necessary voltage translations

3. Remove noise and undesired signals

4. Pre-processing to limit, discriminate and format those signals that would otherwise require excessive processor time

B. Isolation devices shall consist of optical isolators, transformers, relays, and other circuits appropriate to the application.

17.05.05. Batteries and Super Capacitors

A. The use of super capacitors is acceptable for real time clock or other requirements typically preformed by a battery, provided the super capacitor can maintain clock or data for a minimum of 90 days. The use of batteries within control units for maintenance of a real-time clock, or for safe shutdown must be approved by the Authority.

B. If approved by the Authority, all batteries shall be implemented as follows:

1. Batteries shall be sized to retain data for at least six months without charging, and shall be located such that leakage cannot damage any control system components.

2. Battery life shall be no less than 5 years, regardless of type.

3. Systems using standby or back-up 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 periodic maintenance.

4. Batteries shall not be connected by soldering.

C. Necessary RAM control data shall not depend on battery back-up, but shall be stored in non-volatile memory and "shadowed" to RAM for use.

17.05.06. Maintenance and Related Tools

A. Portable Test Unit (PTU) and Bench Test Equipment (BTE)

1. For custom software that is resident in test computers, the Authority shall be given a license for unlimited use of the software for the approved purposes of this Contract. Licenses shall not be linked to specific hardware serial numbers. In addition, PTU and BTE equipment software documentation, compliant with this section, shall be furnished. PTU and BTE software shall be subject to the approved Configuration Control Plan of this Section. The operating system employed for the PTU shall be the most-advanced, user-friendly system available at the time of system design and development. While it is anticipated that the system will 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 Authority at the time of design review.

17.06: RELIABILITY

A. If more than two maintenance releases of any individual software configuration item (SCI) are required during formal type testing through the end of the warranty, the Contractor shall perform a full independent software quality review. This review shall include all aspects of a software audit as listed in this section plus a full independent software verification and validation of the software.

17.07: SAFETY

A. The use of software in safety-critical or related applications must be approved by the Authority.

B. If the Authority approves the use of software in a safety-critical or related application, it shall be developed in compliance with EN-50128 SIL4. In addition to the requirements of this Section, any software, firmware, processing device or computer providing a safety-critical function shall comply with the requirements of T 02.06, Vehicle Design Requirements, Safety.

17.08: CDRL ITEMS REFERENCED

CDRL 17-01, “Contractors Car Level Software Quality Control Plan”, (Ref: T 17.04.04.B)

CDRL 17-02, “Suppliers Software QA Audit Report”, (Ref: T 17.04.04.C)

CDRL 17-03, “Contractors Software Configuration Control Plan”, (Ref: T 17.04.04.E.1)

CDRL 17-04, “Software Delivery”, (Ref: T 17.04.04.F.1)

CDRL 17-05, “Software Documentation”, (Ref: T 17.04.05.A)

CDRL 17-06, “Software Requirements Specification”, (Ref: T 17.04.05.B)

CDRL 17-07, “Unit Test Report”, (Ref: T 17.04.08.C)

CDRL 17-08, “Type Test Results”, (Ref: T 17.04.08.D)

17.09: REFERENCES

17.09.01. Standards Referenced

IEEE STD 1558-2004, "Standard for Software Documentation for Rail Equipment and Systems"

IEEE STD 730.1-1995, "IEEE Guide for Software Quality Assurance Planning"

Mil-HDBK-217 - Military handbook reliability prediction of electronic equipment

CENELEC EN 501288, “Communications, signaling and processing systems. Software for railway control and protection systems”

49 CFR, Part 236, Subpart H, Appendix C, “Standards for Processor Based Signal and Train Control Systems, Safety Assurance Processes and Criteria”.

17.09.02. Technical Specification Cross References

T 02, Vehicle Design Requirements
T 16, Vehicle Monitoring System
T 18, Materials and Workmanship

PART T 18.00
MATERIALS & WORKMANSHIP

Table of Contents

18.01: GENERAL

18.01.01. Quality

A. All materials entering into the construction of these vehicles shall be generally accepted in the industry and shall conform to the requirements of this specification. All materials shall perform safely and satisfactorily within their operating environment and in accordance with their intended function.

B. Workmanship and Quality shall conform to the best manufacturing practices in all respects. All work shall be performed by qualified personnel, using the correct application of tooling and procedures. Personnel shall be properly trained and skilled in the tasks they will be performing.

C. This section is applicable to all parts of the vehicle, whether furnished by the Contractor or by any sub-suppliers, including the internal design and construction of equipment furnished by all suppliers.

D. Surfaces exposed to passengers, crew, or maintainers shall be smooth and free of burrs, sharp edges or corners, and dangerous protrusions. Exposed, sharp sheet metal edges resulting from cutting or die operations shall be deburred. The vehicle design shall avoid pinch points, tripping hazards, snagging points, water traps, and debris accumulation points.

E. Carbody structural parts that are permanently covered and concealed after assembly shall not be made of copper, copper bearing aluminum alloys, brass, bronze, silver, or nickel.

F. Foreign matter, such as shavings, chips, etc., shall be completely removed from all parts of the vehicle, its components, assemblies and subassemblies, whether hidden or exposed.

G. Materials for the construction of the vehicle shall be in accord with the stated specification or cited standard, unless the Contractor obtains written approval from the Authority for a substitution. Single-source materials shall not be permitted unless approved by the Authority. Specification equivalency and benefit data for any substitution to a cited standard shall be submitted to the Authority for review and approval.

H. All materials intended for use on this contract must be procured by the Contractor or his suppliers. The Authority will not act as an agent for the Contractor in purchasing any material for use on this contract.

18.01.02. Standards

A. All materials shall conform to FRA, APTA, AAR, AISI, ANSI ASTM, ASME, IEEE and other specifications as stated herein or as otherwise applicable. Alternate standards may be proposed for consideration, but must be supplied in English, with a narrative comparing both standards, and citing justification why the substitution is equivalent.

B. Whenever a commercial material is not covered by a specification or cited standard, the Contractor shall identify the material by the commercial trademark, name, and address of the supplier. The Contractor shall maintain records that trace all materials to their manufacturers, and shall verify compliance with quality standards specified or cited in these Provisions. For each material used in the manufacture of the vehicle, the Contractor shall submit a description and the technical data specifications of the material composition, including conditions used (e.g. heat treatment, hardness, post-welding treatment, etc), for approval. [CDRL 18-01]

C. Where alternative, or foreign standards are proposed by the Contractor, the Contractor shall submit documentation for Authority review; a copy of the proposed standard in English, with a narrative citing the reasons why the alternative standard is proposed, and including a detailed comparison of the differences and equivalencies between the specified standard and the proposed standard. This narrative shall describe the benefit to the Authority for the alternative standard adoption, and fully substantiate the use of the alternative standard. Use of any alternative standard will be at the sole discretion of the Authority.

D. The most recent standards and specifications applicable at the time of issuance of the Notice to Proceed shall apply unless otherwise specified, or approved by the Authority.

18.01.03. Marking and Storage of Material

A. All new materials intended for use on these vehicles shall be marked or stored so as to be readily identified, and shall be adequately protected during handling and storage. All stored material subject to corrosion shall be adequately protected by waterproof covers, coatings, or packaging to prevent damage. Equipment covers, cable entrances, and openings shall be suitably closed to prevent ingress of water or dirt.

B. All dated material shall have the expiration date clearly marked. Expired material shall not be used.

C. Material or components, which require maintenance during storage, shall be properly maintained per the component(s) manufacturer's instructions. The Contractor shall document such maintenance, and provide these records as requested by the Authority.

D. Rejected or damaged material shall be clearly marked, dispositioned, and stored separately from all other material.

18.01.04. Cleaning Agents

A. A list of recommended cleaning agents shall be provided to the Authority for all materials exposed to normal cleaning operations. This information shall also be included in the maintenance documentation for the vehicle. Hazardous levels of any agent shall not be specified or required.

B. All materials exposed to cleaning operations shall be unaffected by the cleaning agents specified.

18.01.05. Prohibited Materials

A. The following materials shall be prohibited from use on the vehicles:

- PVC
- Asbestos
- Cadmium (except for battery)
- Lead (except in solder used for electrical purposes)
- PCBs
- Carcinogenic materials as listed by current Publication of Threshold Limit Value (TLV) and Biological Exposure Indices (BEIs) guidelines published by the American Conference of Governmental Industrial Hygienists (ACGIH)
- Materials that, in their normal installed state, emit products that are known to be toxic or irritants as per materials listed in 29 CFR 1910.19
- All CFC and HCFC compounds classified as ozone depleting substances per 40 CFR 82.
- Urethane Foam.

18.01.06. MSDS/TSDS

A. The Contractor shall submit a copy of all Material Safety Data Sheets (MSDS) and Technical Data & Specification Sheets (TSDS), for all chemical materials (paints, solvents, adhesives, caulking, etc) used in the manufacture of the vehicle. MSDS and TSDS shall also be provided for all lubricants used in the completed vehicle. The Contractor shall also provide MSDS and TSDS information for recommended cleaning agents and as requested by the Authority for any additional material in question. Information shall be in a form compliant with the requirements of ANSI Z400.1. [CDRL 18-02]

18.02: JOINING AND FASTENINGS

18.02.01. General

A. Fastening to structural members shall be done only on the low stress portion of the member and shall not be located within 3/4"" (17 mm) from the open edge of the structural member.

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

C. Insulating and moisture-proofing materials, as applicable to the materials being joined, shall be utilized in accordance with the manufacturer's recommendations in a manner accepted by the Authority.

D. Extreme care should be exercised in joining materials or components to ensure that the finished product is free from rattles and objectionable noises.

E. Where materials are riveted or bolted to metal, contact surfaces shall be free of dirt, grease, rust and scale and, except for stainless steel parts, shall be coated with a metal base primer which will not interfere with later finish coating application.

1. Where gaps greater than those permitted by accepted drawings or standards are found to exist, metal shims shall be used with the written permission of the Authority.

a. When used, shims shall be made of the same material as that of the deficient metal part and shall be permanently fastened to one of the base parts being joined.

b. The use of epoxy or other plastic filler at such locations is expressly prohibited.

F. All joints between aluminum, steel, or stainless steel, shall be suitably insulated from each other to prevent corrosion.

G. Where wood and ferrous metal surfaces are placed together, the wood shall be coated with Authority approved epoxy paint.

H. Wood-to-aluminum connections shall be in accordance with "Specifications Covering Use of Aluminum in Passenger Carrying Railway Vehicles" in accordance with Technical Report Number 524 by the Aluminum Company of America.

I. All hidden metal, except stainless steel, shall be given one heavy coat of Authority accepted metal base primer and one coat of accepted sealer.

J. All hidden wood, including edges of plymetal panels, shall be given two coats of an Authority approved epoxy paint.

K. Hidden metal and hidden wood is defined as metal and wood that will be subsequently covered by other materials in the completed vehicle.

18.03: FASTENERS

18.03.01. General

A. Fasteners used throughout this vehicle shall be Metric. Contractor may propose fastener standards for use on this project, subject to Authority review and acceptance.

1. Components that are only available in inch standard units or those that have already been qualified on Authority property may be proposed on a limited basis for Authority consideration.

B. All threaded fasteners shall be 6 mm in diameter or larger. Smaller fasteners may be accepted by the Authority on a case by case basis.

C. Visibly exposed screws, mounting bolts or fastenings shall be minimized. No protruding screws, rivets, mounting bolts, or similar items shall be permitted on the exterior of the vehicle. Interior fasteners shall be countersunk where possible, or have low profile heads where countersinking is not possible. Interior fasteners shall not protrude enough to become a tripping or snagging hazard.

D. Torch cutting of holes in any part of vehicle assembly or components is specifically prohibited.

E. Undercar equipment shall not be supported by bolts in tension.

F. The number of different sizes and styles of fasteners used shall be minimized. Fasteners shall be properly marked per the system adopted. All threaded fasteners shall comply with ANSI/ASME B1.13M, unless otherwise specified or approved. All structural threaded fasteners shall have rolled threads.

G. Self-tapping or thread forming screws shall not be used in areas requiring dismantling for servicing.

   1. Use of self-tapping screws shall require specific Authority acceptance for individual application.

H. At least 1 ½ threads shall be visible beyond all nuts. Bolts smaller than 6 mm (0.25 in) shall not project more than 1 ½ thread plus 6 mm (0.25 in). Bolts 6 mm (0.25 in) or larger shall not project by more than 8 threads.

I. Tapped thread depth shall be no less than the diameter of the fastener.

   1. All drilled and tapped mounting holes shall be drilled using a fixture to ensure part interchangeability.

   2. Tapped aluminum utilizing helicoil inserts, or equivalent, may be proposed by the Contractor for consideration by the Authority.

J. Fasteners exposed to the riding public shall comply with the following:

   1. All exposed fasteners on the interior shall be stainless steel, chrome plated or finished to match the surfaces being joined.

   2. All exposed fasteners on the exterior of the carshell shall be stainless steel, unless otherwise specified.

   3. Exposed screws shall be of an approved, tamper-proof type.

K. Fasteners not exposed to passengers and those used undercar shall be property class 8.8 zinc-plated steel. The Contractor shall submit a list of applications under which property class 10.9 fasteners are required, subject to Authority approval. [CDRL 18-03]

   1. Fasteners that join stainless steel components shall be stainless steel.

L. Testing shall be performed using sample quantities as proposed by the Contractor and approved by the Authority. Tests conducted shall confirm that fastener material meets specified chemistry and strength requirements. The Contractor shall obtain certified test results from the testing laboratory and hold the documents for a period ending no sooner than the termination date of the warranty period for the last car. The reports shall be available to the Authority on request.

M. All fasteners shall be properly torqued. Torque values for the application of fasteners shall be in accordance with fastener industry standards and specified on the appropriate application drawings.

1. Torque marks or stripes extending from the secured hardware to the surrounding surface for fasteners threaded into blind holes, or to the nut and bolt end of through bolted assemblies, shall be applied to all safety related hardware, including truck, door, and brake equipment bolts.

2. Tightening indication may be required on other non-safety related hardware upon the Authority's request.

3. The torquing system used by the manufacturer shall be part of the Quality Assurance Plan submitted by the Contractor and approved by the Authority. Refer to TS19, Quality Assurance.

N. When bolts are used to secure apparatus and the bolt head is inaccessible, a mechanical locking device shall be used to prevent the bolt head from turning when the nut is being applied or removed.

1. Where rows of inaccessible bolt fastenings are required, a tapped stainless steel plate with minimum thickness of 0.375" (9.5 mm) shall be welded to the supporting structure.

O. When nuts are difficult to access, they may be contained within a welded cage or welded in place. Threaded inserts that are physically restrained from spinning may be used.

P. All cotter pins shall be stainless steel.

Q. All fasteners used to secure access covers, doors or panels to equipment boxes or interior panels shall be made captive to the panel in which they are used.

1. Where access for service is expected more than every five years, access panels shall be equipped with quarter turn fasteners or over-center latches.

2. Quarter turn fasteners shall have a minimum shank diameter of ¼ inch and be of adequate strength for the intended service.

R. Stainless steel fasteners are preferred in all applications exposed to high temperature connections such as used in mounting and in making connections to resistors and other heat-producing apparatus. If approved by the Authority, plated steel screws or bolts, nuts, flat washers, and lock-washers may be used in high temperature applications. These fasteners shall be suitable for high temperatures without degradation of the strength or corrosion resistance.

S. Flat washers shall be used on both sides of all electrical connections (under bolt head and under nut). Nylon insert type fasteners shall not be used in high temperature applications.

18.03.02. Fastener Materials

A. Fastener component materials (screws, nuts, washers, etc.) shall be properly selected for the application and shall not be mixed within an assembly. All fasteners shall be stainless steel, or steel finished with protective coating such as passivation, dichromate, or zinc plating, depending on the specific application.

B. Threaded aluminum fasteners shall not be used.

C. Stainless steel nuts and bolts shall be used for stainless-to-stainless joints. Anti-seize compounds shall be used on all stainless steel fasteners threaded into stainless steel, or using stainless steel nuts.

D. Metric Fasteners shall conform to the following requirements:

1. Carbon steel Metric threaded fasteners shall conform to SAE J1199, or the current equivalent, specified, DIN or ISO standards. Carbon steel fasteners 6mm diameter and above shall be property class 8.8 minimum for external threads, property class 8 minimum for nuts, per ISO 898/1 and ISO 898/2.

2. Stainless steel fasteners shall be manufactured from A2 or A4 grade, austenitic stainless steel with a minimum property class of 70 per ISO 3506-1979, with a minimum nominal tensile strength of 700 MPa.

3. Non-structural screws, such as Phillips or slotted head screws smaller than 6mm diameter, may be property class 4.8 minimum for steel, property class 50 for stainless steel. Manufacturing tolerances shall be according to DIN 267, part 2, m (medium class)

E. Locking Requirements

1. All threaded fasteners shall be self-locking or provided with locking devices. Locking devices shall be lock wire, lock washers, torque patch, or prevailing torque type locknuts as appropriate for the application or service. Lock wire, if used, shall be stainless steel. Thread locking liquids may be approved on a case by case basis.

2. Prevailing torque locknuts shall be of the nylon collar insert type. Previously installed and removed locknuts shall not be re-used. High temperature applications may use metallic distorted thread locknuts upon Authority approval.

3. Bolts for use with prevailing torque locknuts shall not be drilled for cotter pins or lock wire.

4. All locknuts shall comply with the Industrial Fasteners Institute requirements regarding locking ability.

5. When oversized or slotted holes are provided for installation tolerance allowance, flat washers, of suitable size to cover oversized holes or slots shall be used. In this case, at least one hole shall be of close tolerance to ensure accurate positioning of component. If slotted holes are provided as a means of adjusting a piece of equipment, a secure method of fixing the adjustment shall be provided, such as adjustment screws, ribbed or toothed adjustment washers, Drilled holes and pins, etc.

18.03.03. Plating & Treatment of Fasteners

A. All steel fasteners shall be zinc plated with the highest protective service condition available per thread configuration. Stainless steel fasteners shall be passivated.

B. Chrome plated, steel fasteners used for interior, cosmetic applications shall be chrome plated per ASTM B 456, class SC-3.

C. If stripping and re-plating of fasteners is required to meet the aforementioned criteria, documentation must be made available to verify that all applicable post plating treatments and standards have been met. The Authority may require batch testing of stripped and re-plated fasteners to ensure there is no hydrogen embrittlement.

D. US Standard

1. After manufacturing, steel fasteners shall be electroplated, zinc with a yellow chromate conversion per ASTM B633, Type II - Yellow (please refer to table for thickness).

E. Metric

1. After manufacturing, steel fasteners shall be electroplated, zinc with a yellow chromate conversion per ISO 4042, (please refer to table for thickness).

Plating Thickness for Steel Fasteners, Zinc, Yellow Chromate Conversion			
Bolt size	**Metric DIN 267**	**US ASTM B633**	**Thickness (Micro meter / inch)**
Dia, up to #8 (M3)	A1L	-	3µm / .00012"
Dia. >#8 (M3) to 5/16" (M8)	A2C or A2L	SC1	5µm / .00020"
Dia. >5/16" (M8) to 7/8" (M22)	A3C	SC2	8µm / .00031"
Dia. >7/8" (M22) to 1-1/8" (M33)	A4C	SC3	13µm / .00051"
Dia. >1-1/8" (M33) and greater	A5C	-	15µm / .00059"

F. Hydrogen Embrittlement

1. Fasteners or fastener components with hardness greater than or equal to 320 HV (32 HRC) are susceptible to hydrogen embrittlement when these parts are pickled and/or electroplated. This may cause these fasteners to fail at relatively low loads even if stress relief annealing (baking) is performed after plating. Examples of

hardened fasteners are steel bolts - US Grade 8 (Metric property class 10.9), hardened steel washers, spring washers, etc. These types of fasteners shall be mechanically plated per ASTM B695-00 Standard Specification for Coatings of Zinc Mechanically Deposited on Iron and Steel to avoid hydrogen embrittlement.

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

18.03.04. Riveting

A. Rivet holes shall be accurately sized, located, and aligned for the intended rivet. Rivet holes that have been repaired or holes from which the rivet was removed shall be reamed to the next larger rivet size for use with a larger rivet. Rivets exposed to passengers on the outside of the vehicle shall be stainless steel.

1. Hand-driven steel rivets shall be driven hot and shall completely fill the holes.

2. Mechanically-driven rivets shall be driven cold.

3. Heads shall be concentric with the shank of the rivet.

4. Exposed heads shall be free from rings, fins, pits and burns.

5. All rivets that have been removed and replaced shall have the holes reamed out and the next larger size rivet driven.

6. Joints shall be properly fitted. Metal to metal surfaces to be fastened together by bolts or rivets shall be free of dirt, oil, grease, rust, scale and weld spatter and any rust or mill scale present must be tight and adherent.

B. Two part swage-locking rivets consisting of a pin and collar (such as Huck-Bolt types) shall conform to military specification MIL-P-23469, and be installed such that the pin breaks flush with, or slightly above, the end of the collar.

C. Blind rivets may be used subject to Authority approval. Blind rivet materials may be stainless steel, or plated carbon steel with plated steel or stainless steel mandrels compliant with SAE J1200. The mandrel shall break flush or slightly below the surface of the rivet head, but shall remain locked in place as a structural part of the rivet assembly. All rivets shall be installed according to the rivet manufacturer's instructions, using equipment approved by the rivet manufacturer.

D. Rivet nuts shall be of the positive locking variety, with either exterior serrations or hex cross sections to preclude spinning once installed. The rivet nut hole shall be made per the rivet nut manufacturer’s recommendations.

E. Aluminum alloy rivets shall comply with Aluminum Association Standards for Aluminum Mill Products alloys and tempers 6061-T6 or 6053-T61. Alternate materials may be proposed for Authority consideration.

18.04: STAINLESS STEEL

18.04.01. General

A. All stainless steel components which are connected to adjacent components by welding shall be ANSI type 201 or 301 and shall conform to the requirements of ASTM A666, except as specified otherwise. Where Austenitic Stainless Steel is to be used for structural use, it shall be in accordance with APTA SS-C&S-004.

B. The Contractor shall submit for Authority review and approval a test and inspection plan for acceptance of structural stainless steel to be used in welded applications. [CDRL 18-04]

1. The test and inspections shall verify and certify that stainless steel to be used in welding applications conforms to the requirements of this Part (TS18.00) before any stainless steel parts are manufactured.

2. The test and inspection plan shall include a test procedure and sampling rate for checks of susceptibility to intergranular corrosion. Also included shall be a provision for submission of reports and certifications to the Authority for each shipment.

3. In addition, welding procedure qualification records shall include the testing of the welded specimens for sensitization conforming to ASTM A262, practice A and E.

18.04.02. Structural Design

A. All structural components of stainless steel shall be designed in accordance with the requirements of American Iron and Steel Institute's "Stainless Steel Design Manual."

B. Proper allowances shall be made for the effects of welding, fatigue, column and plate stability, and for the non-isotropic properties of work-hardened stainless steel.

18.04.03. Buffing and Polishing

A. Buffing and polishing of stainless steel, where required, shall be done in an acceptable manner and without the use of any composition containing iron or iron oxide.

18.04.04. Finish

A. Stainless steel in locations to be painted shall be given a #36 grit finish using a belt sander or similar tool, thoroughly cleaned with a solvent and given a coat of Epoxy Primer, Du Pont 823-Y-67635, or an Authority accepted alternative for paint preparation.

B. Stainless steel in locations to be unpainted shall be arranged with finish oriented in a horizontal direction on the exterior of the car, and in a direction to suit the decorative treatment in the interior of the car.

18.05: HIGH STRENGTH LOW ALLOY STEEL

18.05.01. General

A. High Strength, Low Alloy (HSLA) steel, where used, shall be a readily weldable, corrosion-resistant steel with atmospheric corrosion resistance of at least four times that of carbon structural steel without copper (Cu 0.02% max.), shall conform to the latest edition of ASTM Specification A588 or A606, and shall have a smooth surface free of pitting. HSLA steel shall also be in compliance with APTA SS-C&S-034 HSLA Steel.

B. Mill test certificates of chemical and physical properties of structural shapes, plates, bars and sheets shall be submitted to the Authority for each heat of steel used in the construction of these vehicles. [CDRL 18-05]

C. Heat treated parts made of HSLA steel shall be certified for chemical and physical properties. Certification, including hardness test results, shall be furnished to the Authority. [CDRL 18-06]

D. HSLA shall conform to ASTM A568, A588, A6.

E. Vessel quality steel shall conform to ASTM A 515/516 Grade 70.

18.06: STEEL CASTINGS

18.06.01. Quality

A. All castings, unless otherwise specified, shall meet the requirements of AAR Specification M-201 Grade B. Truck frame steel castings may be designed in accordance with another standard if the Contractor can justify that the standard is best suited for the intended heat treatment and composition, with successful past usage in railway passenger service.

B. Steel castings shall be sound throughout (e.g. no voids, no hot tears, no structural discontinuities, etc.).

C. The manufacturer shall prove his manufacturing procedure by either destructive or non-destructive means.

D. Following the establishment of a satisfactory procedure, quality control shall be maintained by testing one or more of each lot at a frequency to be determined by the Authority, the Contractor and the foundry. The frequency shall be influenced by the criticality of the part.

E. If castings are found to be porous or otherwise unsound, the castings shall be destroyed and replaced at no expense to the Authority.

F. Magnetic particle inspection of all surfaces of each casting shall be conducted by personnel certified to SNT-TC-1A.

G. Radiographic inspection conforming to ASTM E94 and using reference radiographs conforming to ASTM E446 shall be performed.

1. With respect to truck castings, Severity Level 3 of ASTM E446 is required in all critical areas of such castings, with Level 4 permitted in all other areas. After compliance with such severity levels has been demonstrated, the sampling frequency for truck casting shall be two castings. The Authority shall inspect the first and one other at random out of the remainder produced.

2. During demonstration that the stated severity levels conforming to ASTM E446 have been met, successive trucks produced shall be re-inspected by radiograph in any defective areas shown in the prior radiographic inspection.

H. A written report of the results of the test and inspections as specified above shall be furnished to the Authority for each lot of castings produced. [CDRL 18-07]

I. See TS 11.15.03, Truck Frame Quality Testing, for additional information.

18.06.02. Heat Treating

A. All steel castings used in the truck structure shall be made of heat-treated electric furnace or controlled open-hearth steel.

B. Where physical strength is gained by heat treating, a physical test shall be conducted on each treating charge of each heat of castings.

C. Where more than one heat is represented in a treating charge, a physical test shall be conducted on each heat represented in each treating charge.

D. The casting manufacturer shall submit all yield, tensile and Charpy impact results for Authority review and approval. [CDRL 18-08]

18.06.03. Castings

A. Steel castings used in locations not referred to herein shall be selected for composition and characteristics best suited to the application, by the Manufacturer or Contractor concerned, but shall be subject to review by the Authority.

18.07: ALUMINUM

18.07.01. General

A. The aluminum materials shall be identified by designations as issued by the Aluminum Association and shall conform to the Specifications contained in the Association's publications "Aluminum Standard and Data".

B. Aluminum that is to be used for structural applications shall be in accordance with APTA SS-C&S-015.

C. Aluminum alloy castings shall conform to ASTM Specifications B26, B85 and B108 for, respectively, sand, die, or permanent mold castings.

D. Where unpainted aluminum is used for interior trim exposed to wear, it shall have a clear anodized finish.

E. The finish shall be the Aluminum Company of America's "Alumilite 204" with a minimum coating thickness of 0.0004" (0.01 mm) and a minimum coating weight of 21 mg/in 2 (3.26 mg/sq cm), or accepted equal.

F. Aluminum structural material used for repairs shall comply with the applicable requirements of the Aluminum Association.

G. Aluminum plate, bar, sheet and extrusion shall conform to ASTM B221.

H. Copies of all test reports for sheet, extrusions and forgings, if used, shall be submitted to the Authority for acceptance.

18.07.02. Fabrication and Fastenings

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

B. Exposed welds shall be uniform, straight and smooth and meet all AWS D1.2 criteria.

C. Fabrication techniques shall be such that the corrosion resistance of the aluminum shall not be impaired and the surface finish shall not be marred or discolored during construction.

D. The specified measures to be taken to prevent risk of contact and resultant possible electrolytic corrosion shall depend upon determination of the most suitable method which can be adapted to the design involved. The following instructions are given for general guidance.

1. Aluminum alloy surfaces shall not be secured to, nor make direct metal-to-metal contact with, the surfaces of copper, brass, bronze, silver, nickel, nickel-plated parts or alloys thereof, lead, tin, ferrous materials, or wood.

    a. The surfaces of aluminum alloy parts secured to steel parts shall be protected as prescribed herein, with a one-part polysulphide or a silicone sealant used as the joint compound.

    b. Alternatively, an insulating joint material which completely covers the mating surfaces may be used.

    c. The joint material shall be non-hygroscopic and if fibrous, shall be impregnated with bitumen or other water-repellent substance.

2. Wood shall not be placed in contact with aluminum alloy except where specific permission has been granted by the Authority.

    a. In such applications the aluminum alloy shall be painted with zinc chromate primer and the wood shall be thoroughly dried and then given two coats of aluminum paint which conforms to Federal Specification TT-P-38 (although this standard is currently withdrawn, it is still applicable to these requirements).

3. Wood blocks or strips secured to the aluminum structure shall not be used for the attachment of interior linings or moldings.

    a. Fiber blocks or an all-metal attachment shall be employed for the attachment of interior linings and moldings.

4. Some form of surface covering or insulation shall be provided to all bolts, rivets, securing clips and devices to prevent contact with the aluminum alloy, if the bolt or other device does not consist also of a compatible aluminum alloy.

5. These instructions shall not be construed to supersede conflicting recommendations by the aluminum manufacturer.

18.08: ELASTOMERS

18.08.01. General

A. Elastomeric parts may include door and window seals, glazing strips, truck bumpers/snubbers, structural and compressible gaskets, and mounting pads.

B. All elastomeric parts shall be composed from suitable elastomers compounded and cured to perform satisfactorily under the intended application and the environmental conditions in which the vehicle may be operated.

C. Elastomeric parts shall be suitably sized for the intended application such that the fit is correct, i.e. no gaps, bulges, stress tears, etc. Gaskets or sealing extrusions shall not bulge, kink, or spread when installed. Seams in joined, extruded gaskets shall be oriented to minimize the possibility of leakage.

D. Elastomeric parts used for interior decorative trim shall be colored to harmonize with adjacent surfaces. All colors shall be as approved by the Authority.

E. Metal parts to which elastomeric materials are cured shall be made of SAE J403 hot-rolled steel or equal, suitably cleaned for bonding. Elastomeric materials shall be tested to verify compliance with performance requirements as given below. The Contractor shall submit certificates stating compliance with the requirements of the standards.

F. In addition to the tests indicated below, elastomers must pass the combustibility requirements as specified in the Flammability, Smoke Emission & Toxicity section of this specification.

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

18.08.02. Substitute Materials

A. The Authority will consider allowing the use of other material if the Contractor can prove that the substitution of an alternate material will provide equal or better performance.

18.08.03. Truck Components

A. Truck bumpers and snubbers shall be made of neoprene having suitable properties for the application, and providing a service life of at least 7 years when operated daily in the Authority's system, in all expected environmental conditions.

1. As part of truck qualification testing, truck bumpers and shall be tested to verify compliance with the hardness identified in the truck design.

B. Neoprene shall have the highest resistance to abrasion which is compatible with the other characteristics herein specified.

C. Neoprene shall be resistant to oil, grease, and acid.

D. Natural rubber is an acceptable substitute if it is certified to be resistant to abrasion and the contaminants listed above.

18.08.04. Glazing Strips

A. Glazing strips shall meet all of the criteria cited in the applicable sections of the flammability, smoke and toxic gas generation section.

B. Door and window seals shall be of neoprene or EPDM and shall be free of major defects of material and workmanship.

C. The hardness of glazing strips measured with a Shore Type "A" durometer shall be 65 ±5 at a temperature between 70 degrees F (21 degrees C) and 90 degrees F (32 degrees C) and shall conform to ASTM D2240, Method A.

18.09: FLOOR COVERING

A. Floor lining shall be a quartz impregnated epoxy.

B. The Contractor shall submit color/material samples to the Authority for approval, as required in TS 14.02.04, Floor Lining.

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

D. The floor covering shall be permanently secured to the sub-floor with an approved procedure and adhesive system as recommended by the flooring manufacturer. The floor covering and adhesive, if used, shall be resistant to cleaning solutions and solvents normally encountered in rail transit service.

E. There shall be no tears or cracks allowed in the installed floor lining, non-penetrating defects such as blisters, lumps, craters, and deformations shall be no greater than 0.030” (0.76mm) in height difference from the nominal, surrounding thickness, and shall occur no more than the following:

1. Defect diameter ≥ 1” – Not permitted,
2. 1” > Defect diameter > 1/4” – 1 each every 6 feet allowed, but must be repaired,
3. Defect diameter ≤ 1/4” – 3 per 12”x12” square area allowed, with no others closer than 3 feet.

18.10: SAFETY GLASS

18.10.01. Laminated Safety Glass

A. Laminated safety glass shall be used exclusively and shall conform to the following general, manufacturing, and finish requirements:

1. Float glass quality shall conform to ASTM C1036, Type 1, Class 1, quality Q3.
2. If tempered glass is used in the laminate, it shall be fully tempered in accordance with ASTM C1422, surface compression level 3, case depth level B.
3. Edges shall be seamed and ground smooth per SAE J673, Edge no. 4, and sealed with aluminum tape or equivalent.

4. Any overlap of one sheet of glass with respect to the other at an edge shall not exceed 0.031 in (0.8 mm)

5. The thickness tolerance of the individual sheets as supplied shall be held within 0.020 in (0.5 mm)

6. The dimensional tolerance for the cut size dimensions of rectangular shapes, including squareness shall be according to ASTM C1036 Table 2, but not to exceed .040 in (1.0mm). For other shapes, the cut size shall not exceed 1/16 in (1.6mm) of the dimension specified. Unspecified corners shall have a 1/16 in (1.6mm) radius.

7. Masking, if used, shall be applied between the laminated layers of the glass.

8. Tinted assemblies shall use a tinted PVB layer with clear glass laminate.

9. Manufacturers stamp shall be positioned in lower right hand corner as viewed from inside the vehicle.

10. Window glazing shall be bonded with an approved type of plasticized polyvinyl butyl resin in the form of a membrane which shall not be degraded by ultraviolet or visible light or temperatures that can be obtained by solar heating

11. Laminated safety glass shall also conform to the requirements of the applicable classification, as follows:

    a. Group I glass shall:

        (1) Be clear laminated safety glass used for forward facing glazing, i.e. windshields.

        (2) Be coated, if required, to have maximum solar transmittance of 68 percent according to ASTM E424, Method A.

        (3) Meet the requirements of 49 CFR 223, FRA Type I rating, having a minimum thickness of 9/16 in (14 mm).

        (4) Be certified to comply with the requirements of ANSI Z26.1, table 1, item 1.

    b. Group II clear glass shall:

        (1) Be clear laminated safety glass used for operator side windows.

        (2) Be coated, if required, to have maximum solar transmittance of 68 percent according to ASTM E 424, Method A.

        (3) Be certified to comply with the requirements of ANSI Z26.1, table 1, item 2.

(4) Meet the requirements of 49 CFR 223, FRA Type II rating, having minimum thickness of 3/8 in (10 mm).

c. Group II tinted glass shall:

(1) Be tinted laminated safety glass, with a neutral gray tint, used for passenger side, and door windows.

(2) Be coated, if required, to have maximum solar transmittance of 34 percent according to ASTM E 424, Method A.

(3) Tinted to match supplied samples (a neutral gray tint with a visible light transmission of 28% ±2%).

(4) Be certified to comply with the requirements of ANSI Z26.1, table 1, item 3.

(5) Meet the requirements of 49 CFR 223, FRA Type II rating, having minimum thickness of 3/8 in (10 mm).

18.10.02. Tempered Safety Glass

A. Tempered safety glass that may be used for internal glazing and partitions, shall be manufactured to ASTM C1048, Kind FT, Condition A, Type 1 clear, Class 1 clear, Quality q3. (or Class 3, tinted, light reducing).

18.11: PIPING AND FITTINGS

18.11.01. General

A. Pneumatic piping shall be manufactured from ASTM A269, 304L stainless steel, 18 gauge, or ASTM A53, black iron, Schedule 80.

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

C. Hose installations shall be such that kinking, rubbing, straining, and unnecessary swinging are precluded.

D. Supports shall be bolted to structure or welded secondary structure. Supports shall be fabricated from polypropylene, or suitable equivalent.

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

F. Loss of main reservoir air pressure due to cumulative leakage in the entire pneumatic system, not including that required for system functioning, per vehicle, shall not exceed 10 psig in 15 minutes, following a 5-minute settlement period from the point at which the system was fully charged and the air compressor was shut off.

G. The Contractor shall submit piping, tubing, and pressure vessel specifications and data for Authority review and approval. [CDRL 18-09]

18.11.02. Piping and Tubing

A. Piping and tubing shall be adequately supported at least every 24 inches (610 mm) throughout its length and at connections, and must not interfere with the removal of, or access to, other components. A minimum clearance of 0.125 inches (3 mm) shall be maintained on all piping and tubing used in the vehicle. Attachment shall be securely fastening with steel clamps lined with an elastomer, polymer, or approved equivalent, between the pipe and clamp to prevent chafing and vibration.

B. All piping shall be installed without low areas that could form "water pockets".

C. All drain piping shall have a minimum slope of 1/8” per foot.

D. All piping and test fittings shall be installed in a manner allowing for efficient maintenance using the least number of fittings that is practical.

E. Main air piping shall be 3/4" Internal Pipe Size (IPS) or larger.

F. ASTM B88, type "K" annealed, or equivalent copper tubing may be used for air piping above the floor.

G. Air piping on trucks shall be a minimum of 1/2" IPS.

H. All joints in the air piping system shall utilize welded or flanged fittings, except at cutout cocks and at air hose connections. Joints that serve the sole purpose of connecting straight runs of pipe shall not be used. Unavoidable joints in piping shall be made in an approved manner. All inaccessible runs of tubing or piping shall be without joints.

I. Sweat or compression type fittings of wrought copper or cast brass shall be used with type "K" annealed copper tubing.

J. All truck and carbody air hose fittings shall be stainless steel or malleable iron.

K. Cutout cocks shall meet the following requirements:

1. All cutout cocks shall be of the vented type and shall be installed with unions directly adjacent on either side to permit rapid change-out of cocks.

2. Cutout cocks (except those operated from both inside and outside) shall be provided with self-locking handles to prevent accidental operation.

3. Cutout cock handles shall be arranged so that in the open position they are perpendicular to the flow of air, and in the closed position parallel with the flow of air. Handles shall be the type suitable for use of lock wire.

4. All cutout cocks shall be in locations readily accessible and easily operated from inside the vehicle or from the front or side of the car.

L. Piping segments shall be deburred and blown out after cutting, and thoroughly cleaned and capped after fabrication. The Authority reserves the right to verify that piping cleanliness is to the Authority's satisfaction at any time during the production process.

M. After full installation on the vehicle, and before connection or installation of system components, the piping system shall be completely flushed to remove and/or dissolve all contaminants from manufacture and installation. The piping systems shall be purged, following completion of component installation. The Contractor shall submit flushing and cleaning procedures to the Authority for review and approval [CDRL 18-10]

N. Following installation, piping systems shall be pressure tested in accordance with ASME B31.1 or other approved method. All leaks which appear during pressure testing shall be repaired to the Authority's approval and re-tested until acceptable under the approved test criteria.

O. The use of sealing tape (plumber's tape, Teflon tape, etc.) is specifically forbidden in threaded pipe connections.

18.11.03. Air Conditioning System Piping and Fittings

A. Air conditioning refrigerant lines shall be of seamless copper tubing per ASTM B88, type "K" annealed, with sweat type fittings of wrought copper.

B. All piping shall be deburred after cutting and thoroughly flushed and purged with nitrogen after installation.

C. Joints shall be kept to a minimum.

D. Refrigerant samples shall be taken in a method accepted by the Authority to verify the cleaning and evacuation plan.

E. Refrigeration tubing shall be joined using silver solder conforming to Federal Specification QQ-B-654.

F. Refrigeration lines subject to condensation shall be insulated.

18.11.04. Soldering of Piping and Fittings

A. Condensate drain tubing and car body air brake tubing shall be joined using silver solder as previously specified, or 95-5 soft solder where solder fittings are used.

B. Solder joints shall have flux cleaned from tubing and fittings after soldering.

18.11.05. Protection of Piping and Tubing

A. All piping and tubing shall be arranged so as to be protected from damage caused by flying debris or inadvertent damage during equipment maintenance.

18.12: WIRE AND CABLE

18.12.01. General

A. All wire and cable shall be in accordance with AAR RP-585 and the recommendations of APTA RP-E-009-98 section 6.0 (or latest version).

B. New wire and cable shall be soft annealed copper, tinned, stranded, and jacketed with radiation cross linked polyolefin (Exane), or Authority accepted equal, in accordance with ASTM B-33 and AAR Standard S-501.

C. The use of aluminum wire and/or cable is specifically prohibited.

D. The insulation system for all internal wires and cables shall be flame retardant and be specifically formulated to minimize smoke, noxious emissions or corrosive fumes in the event of severe overheating or fire. Materials used for the insulation shall be substantially free (less than 1.0% by weight) of halogens, phosphorus, sulphur and nitrogen. For additional flammability; smoke emission, toxic gas, and fire retardation requirements Ref: TS 18.20.

E. Wires and cables shall be designed to minimize insulation weight and combustible material but shall be resistant to mechanical stresses, fluids and extreme temperatures.

F. A minimum number of different wire types and sizes shall be used in wiring the car.

G. All wires and cables shall be protected against movement, chafing and contact with other components that might cause damage to the insulation.

H. Extra-fine wire stranding shall be utilized on applications subject to repetitive motion

I. The Contractor and each manufacturer of equipment shall submit a sample along with the specifications of each wire size to the Authority for review and approval prior to commencement of production. [CDRL 18-11]

J. All wiring shall be printed with manufacturer's identification, conductor size, voltage rating and temperature rating.

18.12.02. Conductor Size

A. Selection of wire sizes and insulation shall be based on the current carrying capacity, voltage drop, mechanical strength, temperature and flexibility requirements.

B. Maximum wire ampacities shall conform to the NEC (NFPA 70) Tables 310-16 through 310-19, as appropriate based on wire insulation capability and ambient temperature.

C. If more than three conductors are routed in a raceway or conduit, the ampacities shall be de-rated as detailed by NEC - 2008 (NFPA 70) Table 310-15 (B)(2)(a).

D. Control and Communication Train Lines shall be sized for vehicle operation in twelve car train-sets.

E. For wires (insulated conductors smaller than 6 AWG), the maximum finished wire diameter shall be in accordance with MIL-W-81044/9.

F. For power cables (insulated conductors 6 AWG and larger), the maximum insulation thickness shall be in accordance with ICEA-S-66-524, Table 3.1.

G. The maximum jacket thickness for multi-conductor cables shall be in accordance with ICEA-S-66-524, Table 4-7.

H. The insulation system shall fit tightly over the stranded conductor but shall strip freely. The insulation thickness at any point shall not be less eighty-five percent of the average wall thickness as shown in ICEA S-66-524. The outer jacket for multi component cables shall be homogenous and free of lumps and surface defects.

I. Minimum wire sizes used in the vehicle shall be as follows:

1. 14 AWG, for wire pulled through conduits and raceways.

2. 16 AWG, for all other wire, including that laid in raceways rather than pulled through.

3. 18 AWG, for wire within control compartments.

4. 22 AWG, for wire on electronic units, cards, and card racks. Smaller wires may be proposed for Authority consideration on a case-by-case basis.

J. When multi-conductor cables are needed, wire sizes smaller than AWG No. 14 may be used provided that the size selected is satisfactory for the electric load and function this wire is expected to perform.

K. Control and Communication Train Lines shall be sized for vehicle operation in twelve car train-sets.

18.12.03. High-Temperature Wire and Cable

A. High temperature wire and cable shall be used in locations where the operating temperatures will exceed the limits of the other indicated insulations, for example, connections to heaters and resistor.

B. High temperature insulation shall be in accordance with the following requirements:

1. For wire sizes AWG 16 and larger: silicone rubber meeting AAR RP-587.

2. For wire sizes AWG 18 and smaller: Kapton film insulated/liquid H aromatic polyamide covered per MIL W 81381B or abrasion resistant PTFE Teflon meeting MIL-W 22759/6B or 10B as appropriate for the voltage level used. When used for interconnecting pieces of apparatus, this type wire shall be in bundles with a protective covering.

High temperature insulated wire shall not be used in conduit or raceways without specific approval of the Authority. This type of wire and cable shall not be bundled together or run with any other type of cable.

18.13: WIRING

18.13.01. General

A. Where practicable, it is desirable to have the wiring prefabricated into standard harnesses that shall include spare wires. This shall exclude wiring to under-seat heaters.

B. Each harness between equipment locations shall contain a minimum of ten percent spares, but no fewer than two spares for each wire size except that the following wires do not require spares:

1. 120 VAC and 28.5 VDC power supply wires.

2. Lead cables to each single component or piece of equipment.

C. All circuits and branches must be separable to isolate when searching for shorts.

D. Wiring which operates at 120 VAC and 230 VAC shall not be placed in the same conduits or ducts with wires operating at battery voltage.

E. In electrical locker and equipment boxes, wires operating at 120 VAC and 230 VAC shall be cabled separately and not combined with other voltages.

F. When some parts of a given piece of electrical apparatus are to be connected to two different nominal voltages, all wiring thereto shall be insulated for the higher voltage.

G. All wire lengths shall include a service loop that allows for three re-terminations of the wire.

H. Wiring shall be in conduit, raceways or ducts. Exceptions to this requirement may be proposed for Authority consideration on a case by case basis.

I. The vehicle wiring shall meet all the above requirements and all recommendations of APTA RP-E-002.

18.13.02. Application and Installation of Wire

A. Car wiring methods and materials shall be in accordance with Chapter 3 of the NEC (NFPA 70) current issue, except where otherwise required by the Specification, or where permission has been granted by the Authority, and with the exception that all wire shall be stranded.

B. Wiring requirements of IEEE Std 16-2004 shall apply.

C. All wiring shall be performed by or under the direction of qualified and experienced Electricians.

D. The Electricians shall be provided with appropriate tools for skinning insulation, cutting, tinning, soldering, and attaching mechanical or compression type terminals to the conductors.

1. The tools for mechanical and compression type connections must be produced by a single manufacturer.

2. Connectors shall be installed per the manufacturer's recommendations.

E. Care must be taken in removing insulation from the conductor to avoid nicking of the wire or strands of the conductor cable.

F. Wire in ducts and conduit shall be free of kinks, insulation abrasions and insulation skinning.

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

H. Insofar as practicable, all wiring shall be fabricated as harnesses pre-terminated on a bench.

I. Safety grounds shall utilize dedicated grounding bosses or grounding pads.

J. Wiring for communication systems shall be done in an accepted manner to conform to the requirements established by the manufacturer of such apparatus.

K. Conductors of AC and DC current shall be separated by a physical barrier, to be accepted by the Authority.

18.13.03. Undercar and Overhead Wiring

A. Undercar and overhead wire and installation shall meet all recommendations of APTA RP-E-002

B. Power cables shall be twisted between supports in order to cancel undesirable fields.

C. Power train line cables shall be supported by insulated cable cleats on the underside of the vehicle structure with sufficient spacing between individual conductors to permit adequate ventilation.

D. Wire harnesses may be covered with silicone glass cloth tubing and secured to wire supports with cable ties. These wire harnesses may be used only in the ceiling and locker areas.

E. Protection shall be provided for underfloor wiring against damage from flying ballast.

18.13.04. Marking

A. All wires, terminal studs, connection points and connectors shall be plainly and suitably marked with permanent type markings as per APTA RP-E-002, so that circuits may be easily identified. These markings shall conform to a standard wire numbering system submitted to the Authority for review and approval. [CDRL 18-12]

B. Wiring in electrical apparatus shall be marked in conformance with the requirements of IEEE Std 16-2004.

C. Except for spares and wires entirely within an equipment enclosure, each wire of gage AWG No. 8 and smaller shall be permanently and legibly marked along its entire length. Wires of gage larger than AWG No. 8 may have wire markers applied at each end of the wire.

1. Spare wires and wiring entirely within an equipment enclosure may have a single wire marker at each end in lieu of continuous marking, subject to acceptance by the Authority.

2. Wire markings shall be provided every 8 inches.

D. Wires shall be marked by laser etching of the sleeve. As an alternate, markers may be of the printed, heat-shrinkable type. Hand printing is prohibited.

E. Markings shall be non-conductive.

F. Marking material/ink shall not be adversely affected by normal electrical cleaners and solvents.

G. Marking material/ink shall be UV protected to withstand exposure to the elements without discoloration.

H. For proper identification of phases, color coded shrink type markers shall be used on 230 volt cable ends.

I. The proposed wire marking system shall be submitted to the Authority for review and approval. [CDRL 18-13]

18.13.05. Interference and Transient Suppression

A. Wiring shall be carefully planned and selected to avoid electrical interference in the operation of the public address system and the intercom system.

B. Wiring shall conform to the requirements of IEEE Std 16-2004, with respect to interference and transient suppression.

1. This shall include use of coaxial cable, chokes, filters, capacitors, etc., as required by good design standards to avoid possible interference with these systems.

C. Adequate voltage transient suppression shall be provided for the protection of panels and circuitry involving semiconductor devices.

D. In addition, suppressors shall be incorporated across inductive devices to minimize switching transients.

E. Low and high voltage cables shall have separate individual raceways.

18.13.06. Gap and Creepage Distance

A. The minimum gap and creepage distances used shall be per APTA RP-E-004 for all equipment and cabling installation.

B. Electrical clearances in electrical and electronic equipment shall meet the requirements of IEEE Std 16-2004.

18.13.07. Protective Covers

A. All contactors, terminals, exposed wire, connections, etc. which operate at 50 volts or higher shall be covered by an insulating cover or protective boots to protect against inadvertent contact by passengers or operating/maintenance personnel. (Other means of protection may be submitted to the Authority for review and acceptance.)

B. All protective covers or panels shall be secured with self-retaining fasteners.

C. Details of these protective elements shall be included with all system design submittals for Authority review and acceptance.

18.13.08. Solder

A. Solder shall be selected based upon application using IPC J-STD-001, and IPC-HDBK-001 criteria.

B. A flux of non-corrosive type shall be applied immediately before soldering.

C. An automatic temperature controlled solder pot shall be used.

18.13.09. Tape

A. In applications specifically approved by the Authority, an acceptable polyvinyl chloride electrical tape with Buna "S" type adhesive 0.01inch (0.25 mm) over-all thickness may be used.

B. The above materials shall be suitable for use with the conductor insulation without discoloring or corroding the copper wire and shall provide 600 volt insulation.

18.13.10. Terminals

A. Terminals and connections shall conform to the requirements of IEEE Std 16-2004

B. Conductors shall be fastened to connectors by accepted soldering or mechanical methods.

C. Conductors which will be subjected to motion relative to the terminal shall be protected by suitable means to minimize breakage of the conductor at or near the terminal.

D. Crimp terminals shall be used on all wiring operating at 28.5 volts or higher.

E. In general, connections shall be made by means of terminal blocks.

F. The shield on twisted shielded pairs shall not be stripped back more than the amount recommended by the manufacturer of the attached equipment. Stripping of the shield and termination of wires shall not be done in any manner that may compromise the required signal to noise ratio.

G. All heater and other high temperature terminals shall be nickel plated.

18.13.11. Terminal Manufacturer

A. Mechanical or compression type connectors and terminals shall be physically interchangeable and operationally compatible with AMP ring tongue standard connectors and terminals.

18.13.12. Splicing

A. Splicing of conductors is prohibited and shall be permitted only with the express acceptance of the Authority.

B. Only splices meeting all recommendations of APTA RP-E-002 shall be considered for acceptance.

C. When accepted by the Authority, splicing shall be made in junction boxes and the spliced joint shall be mechanically as strong and shall have the same conductivity as any other part of the conductor. Authority accepted solder-less connectors shall be used for splicing.

D. The joint shall be insulated with tape so as to be at least equivalent to the insulation of the conductor.

E. The outside diameter of the spliced portion of the cable after the tape insulation is applied shall not exceed the outside diameter of the unspliced portion by more than 40%.

F. The finished splice shall be painted with one coat of Authority accepted insulating compound.

G. Use of wire nuts is expressly prohibited.

18.13.13. Grounding

A. Battery (low voltage DC) circuits shall not be individually grounded. Grounding of the low voltage DC system shall be in accordance with TS 09.07.04.

B. All equipment enclosures and frames of all resiliently mounted electrical apparatus, with the exception of the battery box, shall be suitably grounded to the car body.

C. All electrical circuits shall be completely insulated from the car body.

D. The car body shall be grounded to each truck bolster (if used) and to each truck frame by means of separate cables in series.

E. The vehicle grounding system shall meet all technical requirements of IEEE Std 16-2004 and of section 4 of APTA SS-E-005-98 (or latest version).

18.14: CONDUITS AND FITTINGS

A. Wires shall not occupy more than 50% of the free cross-sectional area of any conduit.

B. All sharp edges and internal burrs shall be removed to eliminate abrasion of the wire insulation.

C. Except as noted below, all wiring shall be run in electrical metallic tubing (EMT) thin wall steel or heavy wall aluminum conduit.

D. Sufficient pull boxes shall be provided in long conduit runs to facilitate future repair and maintenance. Locations shall be approved by the Authority.

E. Where necessary to facilitate component removal and replacement, minimum lengths of flexible liquid tight conduit may be used with Authority approval

F. Conduit fittings, receptacles, wiring devices and junction boxes for car wiring shall be as manufactured by the Thomas and Betts Company, AMP, Appleton, Crouse-Hinds, Hoffman, Pyle National, or approved equal.

G. All covers for under-car fittings and boxes shall be gasketed using Authority accepted materials and shall meet all emissions and toxicity criteria.

H. Interiors of boxes shall be protected against condensation and corrosion.

I. Insulated bushings shall be used in all conduit and conduit fittings.

J. In addition to the above requirements, undercar and overhead wire and installation shall meet all recommendations of APTA RP-E-002.

18.15: WIREWAYS

A. All wireways shall be of rigid, stainless steel or extruded aluminum construction.

B. The trays shall be adequately supported throughout their entire length.

C. Trays shall be completely de-burred leaving absolutely no sharp edges. Grommet clamps shall be provided at all locations where cables or wires enter or leave the wireways.

D. Interior wireways shall be permitted in approved ceiling interior locations only.

E. Wiring shall not be draped over the edge of the wireways without mechanically attached wireway edge protection.

F. Heads of screws or bolts inside the wireway shall be flush with the metal surface.

G. Metal wireways, elbows, couplings and similar fittings shall be flush with the metal surface.

H. Points of screws or fasteners shall not be directed toward the interior of the wireway.

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

J. The total cross-sectional area of all conductors (including insulation) in a wireway shall not exceed 50% of the interior cross-sectional area of the wireway.

18.16: WELDING

18.16.01. General

A. All welded connections used in the construction or repair of the vehicles and associated equipment shall be described on the drawings which shall be submitted for acceptance by the Authority.

B. All welding practice not specifically covered in this section shall be in accordance with the applicable requirements and recommendations of the American Welding Society (AWS) as contained in the following publications of latest issue:

1. AWS Welding Handbook (AWS WHB).
2. AWS Brazing Handbook (AWS BRH).
3. AWS Railroad Welding Specification – Cars and Locomotives (AWS D15.1)
4. AWS Aluminum Welding Code (AWS D1.2)
5. AWS Structural Welding Code (AWS D1.1).
6. AWS Structural Welding Code Stainless Steel (AWS D1.6/D1.6M).
7. AWS Structural Welding Code - Sheet Steel (AWS D1.3)
8. AWS Filler Metal Procurement Guidelines (AWS A5.0)
9. AWS Recommended Practices for Resistance Welding (AWS C1.1).
10. Other applicable AWS Standards and Publications.
11. Aluminum Company of America Report No. 524, "Specifications Covering Use of Aluminum in Passenger Carrying Railway Vehicles".

C. The Contractor shall demonstrate compliance with AWS welding requirements and standards. Where non-AWS welding is proposed, the supplier shall demonstrate equivalence.

18.16.02. Responsibility

A. The Contractor shall be responsible for the quality of all welding and brazing, including the welding and brazing of its suppliers and Subcontractors.

B. 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 the AWS, or other equivalent qualifying procedure accepted by the Authority.

C. Records of welder qualification tests shall be made available for review by the Authority. [CDRL 18-14]

D. Welders shall have minimum qualification as covered by ASME Code "Welding and Brazing Procedures and Performance Qualification", or qualification in accordance with the applicable requirements of AWS standards, or other Authority approved equivalent standards. Welder qualification tests for pressure vessel welding shall be in accord with applicable requirements of ASME Section IX, or other approved specifications. The Contractor and all suppliers and Subcontractors shall retain records of welder qualifications and shall make these records available to the Authority upon request.

E. Weld integrity test procedures shall be submitted to the Authority for review and approval. [CDRL 18-15]

18.16.03. Test Welds

A. The Authority shall have the right to require the making of test welds by an operator, whether under the direct control of the Contractor or a supplier or subcontractor, at the expense of the Contractor, to determine that operator's ability to produce satisfactory welds of any given type.

B. The Authority shall also have the right to require the making of test welds at the expense of the Contractor, to settle any question which may arise as to the suitability of any welding method or procedure used during production.

C. AWS requirements and recommendations shall be followed in the making of tests and the settlement of other questions which may arise hereunder regarding welding practice.

18.16.04. Cleaning

A. Prior to welding, all faying surfaces of the parts to be joined shall be thoroughly cleaned to remove corrosion, rust, scale, slag, grease, oil, water, and paint in accordance with AWS D1.1, Section 8.5 on Workmanship and Technique.

B. The Contractor or manufacturer shall treat surface marks resulting from welding, so as to eliminate to the extent possible visible defects and discoloration exposed to the passenger's view

18.16.05. Support

A. Parts to be joined by welding shall be supported and held in position by tables, jigs, or fixtures to prevent warping and to maintain their proper interrelation during welding. Weld joint design and welding method shall include provisions for shrinkage and warping due to the welding process. Welding shall be applied in a manner to minimize distortion.

18.16.06. Welding Rod

A. Welding rod, wire, electrodes and filler metal shall be chosen with respect to manufacturer, type and size by the Contractor or his Subcontractor. Filler metal shall be selected per AWS Filler Metal Procurement Guidelines (AWS A5.0)

B. These materials shall be purchased in packages of convenient size, which shall be marked with the manufacturer's name and the specification, diameter and net weight of the material.

C. Welding rod, wire, electrodes, and filler metal shall be stored in accordance with recommendations of AWS D1.1 latest issue, so as to protect them from mechanical and environmental damage.

18.16.07. Control

A. Current, voltage, distance, flame, and other variables shall be controlled to give a smooth weld, free of gas pockets, oxide inclusions, and to minimize variations in the width and thickness of the weld, as well as wandering and spattering.

18.16.08. Weld Penetration

A. Full penetration welds (and partial penetration welds, where specifically accepted by the Authority) shall be in accordance with the requirements of AWS D1.1 latest issue.

18.16.09. Warpage

A. The method of depositing weld metal shall be chosen to minimize warpage and locked-up stresses.

B. 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.

18.16.10. Heat Treatment

A. Where appropriate for the material and welding methods used, heat treatment shall be provided after welding for stress relief and/or strength attainment. Examples for application are parts rotating at high speed or parts subjected to shock and/or vibration, including trucks, end underframes, and other critically-stressed parts

B. Stress relief shall be done in accordance with AWS D1.1 latest issue, the applicable ASTM specification for the material, or the recommendations of the supplier of the material.

18.16.11. Resistance Welding

A. Resistance welding of stainless steel shall be in accordance with AWS Cl.1 latest issue, and shall employ accurate control of current, time, electrode size and shape, and tip force, to produce uniform welds of specified strength which are not subject to intergranular corrosion, stresses or cracking.

B. Resistance welds shall be arranged to avoid tension or "peeling" forces on the welds under any anticipated loading condition.

C. Sample resistance welds in all materials shall be made with calculated settings of current, time, and tip pressure.

D. These samples shall be static ("pull") tested and, in the case of stainless steel elements, "peel" tested to verify adequacy.

   1. A "peel" test is made by attempting to insert a metal wedge between two resistance-welded plates to verify that the weld nugget is as strong as the parent metal.

E. Records shall be maintained, which include the settings and ultimate shear strength of the test samples. These records shall be made available at the request of the Authority.

F. Sample welds shall be made and tested at the beginning of each shift and, in addition, whenever there is a change in any of the following:

   1. Operator

   2. Material, material thickness, or combination of thicknesses

   3. Electrodes

   4. Settings

G. The strength of all resistance weld test samples shall exceed the requirements of AWS Cl.1 latest issue, "Recommended Practices for Resistance Welding," by at least 20% percent.

H. The contact surfaces of resistance welded connections shall be thoroughly coated with a spot weld sealer which has been accepted by the Authority.

18.16.12. Procedures

A. The Contractor, and his Subcontractors, shall establish and follow Authority accepted procedures covering all types of welding indicated.

B. Procedures which shall include the following information, when applicable, shall be submitted to the Authority for review and approval in a standard format prior to any welding being performed [CDRL 18-16]:

1. Type of welding process
2. Welding position
3. Governing specification
4. Type of base material
5. Joint design, type and dimensions
6. Electrode type and diameter, including specification
7. Filler metal type and diameter
8. Type and amount of shielding gas
9. Type and amount of backing gas
10. Amperage
11. Voltage and polarity
12. Arc Length
13. Welding speed
14. Filler wire feed rate
15. Weld preparation
16. Cleaning methods
17. Weld pass sequence
18. Use of chill blocks and back-up bars
19. Method of restraint at joint
20. Preheat
21. Post-heat and stress relief
22. Edge and surface condition
23. Defect limits

C. The Contractor shall also prepare and submit to the Authority, a resistance welding schedule for producing welds for each resistance welding condition to be encountered in production. [CDRL 18-17]

1. This schedule shall be submitted to the Authority after it has been certified to show compliance with the performance requirements by actual or simulated production tests.

2. After acceptance, qualification trials on the various joint designs in the vehicles shall be made.

3. The welding schedules thus developed shall be recorded and production carried within plus or minus 10% percent of the listed values. Changes outside this range shall be re-qualified.

4. Resistance welding schedules shall include the following information, as appropriate, at a minimum:

   a. Material being welded

   b. Thickness of each sheet of material being welded

   c. Electrode diameter, shape and tip radius

   d. Net electrode force

   e. Welding current

   f. Welding Time

   g. Minimum shear strength

   h. Minimum weld spacing

   i. Diameter of fused zone

   j. Minimum contacting overlap

18.16.13. Quality Control

A. As a minimum, the Contractor shall perform the following functions to ensure quality in the welding as indicated.

B. The validity of welding schedules shall be established by tests, macroetch, and visual examination for cracks, indentation and surface condition of representative welds.

C. Destructive tests on joints simulating each resistance welded joint in production shall be performed at random.

1. Unsatisfactory results shall be corrected by adjustment of the welding procedures or schedules.

2. Parts welded since the last satisfactory test welds shall be inspected to determine weld quality, by a test accepted by the Authority.

3. Type of material, thickness and pre-cleaning of the test weld material shall be the same as that used in production.

D. All welds designed to carry primary stresses in members such as side sills, end frames, bolsters and other important frame members, shall be inspected by the Contractor for defective welding.

1. Defects in excess of limits indicated or established in the accepted procedures shall be cause for rejection of the work affected.

2. These limits shall include:

a. Cracks, regardless of length, magnitude, or location

b. Overlaps

c. Lack of penetration

d. Incomplete fusion

e. Inclusions from porosity or slag, deleterious materials or any other cause, except if they do not materially affect the strength of the welded joint and do not indicate improper technique or an unsatisfactory procedure.

f. Undercuts

g. Surface appearance

h. Size of weld

E. Resistance welds shall be rejected if they have the following defects in excess of limits indicated or established in the accepted procedures:

1. Improper penetration

2. Voids, porosity, or cracks

3. Pitted, spattered, or discolored surface

4. Indentation, surface blemishes, or surface wrinkling, (exposed areas only)

F. When a production weld has been determined to be substandard, all production since the previous acceptable production quality control test shall be segregated and disposition shall be recommended to the Authority for acceptance.

1. All parts with substandard welds shall be rejected or re-welded.

2. Re-welded parts shall be in full compliance with these Specifications and the accepted welding procedures.

G. All welding inspectors shall be AWS Certified Welding Inspectors (CWI) in accordance with the applicable AWS provisions, inspectors qualified to an equivalent welding agency's standards which have been accepted by the Authority or inspectors who have trained and qualified by a CWI in good standing.

18.17: CORROSION CONTROL

A. All materials used shall be either inherently corrosion resistant, suitably treated, or coated to resist corrosion. Equipment located in areas highly susceptible to corrosion shall be made from inherently corrosion resistant materials.

1. Areas exposed to corrosive fluids or cleaning solutions shall be protected with coatings resistant to those fluids. The Contractor shall be responsible for verifying that all such areas are protected through communications with the Authority.

2. Except as otherwise indicated, all aluminum exposed to view in finished work in the interior of the vehicle shall have a protective anodized coating.

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

4. The Contractor shall prepare a Corrosion Control Plan, which shall locate all materials that require treatment to prevent corrosion due to atmospheric exposure, and areas of dissimilar metal or other material joining which could result in galvanic action and material deterioration. This plan shall document the methods used to preclude failure due to corrosion for any of the above conditions. The Contractor shall update this document as materials and treatments change. The Corrosion Control Plan shall be submitted to the Authority for review and approval. [CDRL 18-18]

5. The specified measures to be taken to prevent risk of contact and resultant possible electrolytic corrosion shall depend upon determination of the most suitable method which can be adapted to the design involved. The following instructions are given for general guidance.

   a. In the vehicle structure, where the parts are permanently covered and concealed after assembly, components made of copper, copper bearing aluminum alloys, brass, bronze, silver, and nickel shall not be employed.

18.17.02. Dissimilar Metal Treatment

A. Direct contact between electrically dissimilar metals is prohibited except as approved by the Authority for electrical connections between copper and aluminum where appropriate joint compounds are used as specified herein. Isolating and moisture-proofing materials, appropriate to the materials being joined, shall be used at all times.

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

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

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

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

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

18.18: CURED MATERIALS

A. All materials that are applied prior to curing shall be applied according to the manufacturer’s full recommendations, including surface preparation, mixing criteria, application temperature, shelf life limits, pot life limits, curing temperature, curing exposure (before handling or loading), etc.

B. All uncured material shall be stored and applied according to the manufacturer’s full recommendations. All materials shall be used within the specified shelf life limits; material that has exceeded the shelf life shall not be used.

C. Preparation prior to bonding or painting the surface shall be in accordance with ASTM D2651.

18.18.02. Paint and Painting

A. The Contractor shall submit a paint scheme during the design review process that identifies areas to be painted, color used, paint used, and any special process requirements in applying the paint. The Contractor shall furnish a copy of their painting procedure along with paint samples to the Authority for review and approval [CDRL 18-19].

1. All paint must be compatible with the Authority's present paint application apparatus and system, and must be fully repairable within the parameters of restrictive air quality zones and the local governing air quality management Authority. The Contractor shall submit to the Authority for review and approval data on all paints, primers, and application processes or procedures to be used. [CDRL 18-20].

2. The undercoating material shall be applied according to the manufacturer's instructions.

3. Primer, finish paint, and related components shall be supplied as a complete system, manufactured by a single manufacturer. All mixed paint materials shall be used within the first 70% of the mixed pot-life time. Paint shall be applied within the manufacturer's recommended temperature range, but at a temperature no less than 55°F.

4. Preparation for paint application shall follow the paint manufacturer’s recommendations. As a minimum, prior to paint application, surfaces shall be cleaned to remove all traces of contamination and properly treated to promote paint adhesion.

5. Paint shall be applied evenly, and the finished surface shall be free of dirt, runs, "orange peel”, or other imperfections. Paint inspection and acceptance criteria shall be subject to Authority approval. Paint quality control samples may be proposed to establish visual acceptance criteria, subject to Authority approval.

6. Cosmetic coatings of paint shall have specified gloss levels for the appearance desired. The following gloss levels are defined according to common terminology, with the following criteria based upon the ASTM D 523 - 60° axis angle with equivalents shown for 80° and 20°.

Gloss Level Definition	**Glossmeter Setting and Gloss Value**		
	20 degree	60 degree	85 degree
- High Gloss	85-90%	90-95%	95-100%
- Semi Gloss	0-10%	20-30%	50-60%
- Flat Gloss	0%	0-10%	10-20%

7. At least two coats of finish paint shall be applied, with appropriate surface preparation between coats.

8. Touch-up paint shall be identical in all respects to the original paint. Color chips for color match may be provided by the Contractor for Authority approval, to establish acceptable color match tolerances. It is the Contractor's responsibility to ensure that the color match is acceptable. It may be required that the color match be made according to ASTM D2244. In no case shall color mismatch detract from the overall appearance of the equipment.

9. Prior to assembly, all low-alloy steel areas shall be painted with one coat of an approved etching primer followed by one coat of an approved sealer to prevent rusting.

10. All coatings used are to be EPA compliant with Authority’s area requirements.

11. Painted surfaces shall develop full adhesion to the substrate to which they are applied. Testing for adhesion between the paint and the substrate surface shall be done on a random basis and shall conform to ASTM D3359, 3a Classification, using Permacell® #99 adhesion test tape.

B. Surface Preparation

1. Prior to painting any exposed surface, all dents, gashes, nicks, roughness or other surface imperfections or depressions shall be removed to the maximum extent possible by straightening.

2. Any remaining dents or other imperfections shall then be filled with acceptable epoxy based filler and sanded smooth.

3. The maximum allowable filler thickness shall be as recommended by the filler manufacturer for the environment and service to which it is to be exposed but shall not exceed 3/16" (4.8mm) in thickness.

C. Exterior Painting

1. All paint used on the carbody, trucks, exterior components, and exterior of equipment boxes shall be an automotive fleet quality urethane paint system (e.g. DuPont Imron 5000 / 6000 or equivalent) consisting of primers, color coat, and clear topcoat as approved by the Authority. Painted exterior surfaces shall receive a minimum of two coats of primer, one coat of surfacer, and a minimum of two coats of color, and one coat of clear.

2. Areas subject to excessive corrosion, such as under-glazing strips and door seals, shall receive two coats of primer and two coats of color, and two coats of clear.

3. Exposed underfloor/underframe steel surfaces shall receive a minimum of two coats of primer and two coats of an approved paint after installation of welded-on bracketry. In areas where intermittent welding is used, the seam shall be completely sealed after paint application.

4. The exterior of all equipment enclosures shall receive a minimum of two coats of primer, and a minimum of two coats of an approved paint. The interior of all equipment enclosures shall be coated with a primer and an approved white coating. Electrical equipment enclosures shall use an approved non-conductive white coating.

5. The Contractor shall ensure that wireways, conduits, and piping susceptible to corrosion shall receive a minimum of two coats of primer and two coats of an approved paint.

D. Painting Restrictions

1. Any component that would be damaged or suffer impaired performance from painting shall not be painted. These items include, but are not limited to the following:

   a. Wire, cable, flexible conduits and fittings, electrical grounding points

   b. Wearing surfaces, threads used for adjustments, lubrication points

   c. Elastomeric parts, hoses, bumpers, etc.

d. Heat transfer surfaces, resistors, electrical insulators, etc.

e. Moving parts, linkages, gas springs, etc.

18.18.03. Powder Coating

A. Powder coating if used, shall be epoxy based for interior surfaces and polyester based for exterior surfaces with the appropriate UV resistance level for the intended application. Finished film thickness shall be 3.5 mil (0.089mm) ± 1.0 mil (0.025mm). The surface preparation and pre-treatment shall be according to the powder manufacturer's recommendations.

B. Powder coating finish gloss level for cosmetic surfaces shall be according to Powder Coating Institute, Gloss Level Standard(s) – 7 to 10.

18.18.04. Adhesives

A. Adhesives to be used for installation of floor covering, panels, insulation, and vibration isolation materials shall have a satisfactory history of performance in a rail transit environment.

B. A list of all adhesives to be used, including location, technical data & specification sheets, and flammability properties, shall be submitted to the Authority for review and approval. [CDRL 18-21] Adhesives used in small quantities may not require flammability data, subject to Authority's approval.

C. Joining of components by adhesives shall be completed within the maximum working times as follows:

1. The application and aligning of bonded components shall be completed within 70% of the adhesive's maximum working time, considering application conditions.

2. When two-part compounds are being used, only the amount of adhesive that can be used within 70% of the maximum recommended pot life shall be mixed.

D. Adhesives that use atmospheric or humidity cure shall be installed such that the air circulation to fully cure the adhesive is possible.

E. Adhesive selection and bonded joint design shall consider MIL-HDBK-691B.

18.18.05. Sealants & Caulking

A. The use of caulking and sealing compounds shall be minimized.

B. Caulking and sealing compounds shall be applied in accordance with the manufacturer's instructions and recommendations, shall be non-staining, and shall be supplied in colors closely matching those of adjacent materials and surfaces. Caulking used in exterior applications shall be ultraviolet light (UV) resistant. If butyl-type is used, it shall be extruded polyisobutylene sealer compound of 100 percent solids.

C. Caulking primers shall be quick-drying, colorless, non-staining sealers of a type and consistency recommended by manufacturers of caulking materials for the particular surface involved.

D. Packing (backstop) shall be non-staining, resilient material, such as fiberglass roving, neoprene, butyl, closed-cell foams, or other compressible materials compatible with the caulking compound used. Joints, spaces, and junctures to be packed and caulked or sealed shall be completely cleaned of dirt, dust, oil, and other foreign materials that would adversely affect caulking quality. Suitable primer shall be used to achieve full adhesive bond.

E. Surfaces shall be thoroughly dry before caulking compounds are applied. Caulking compound application shall be compatible with prior or subsequent paint application. When so stipulated by the sealant manufacturer, paint and other protective coatings shall be removed from surfaces to be caulked prior to priming and application of sealants.

F. Compounds shall be applied with pneumatic guns. Where the use of a caulking gun is impracticable, suitable hand tools shall be used.

G. Unless otherwise indicated, the entire perimeter of each opening shall be caulked.

H. The finish of caulking joints on flush surfaces and in internal corners shall be neatly pointed; excess material shall be removed; and, where exposed, the caulking shall be free of wrinkles and uniformly smooth.

I. Application of polysulfide or silicone compounds shall be in accordance with the manufacturer's instructions and recommendations.

J. Compounds shall not be used when they become too gelled to be discharged in a continuous flow or exceed their stated shelf life, and they shall not be modified by addition of liquids, solids, or powders. Compounds shall be installed within the manufacturer's defined temperature range.

K. Installation and working of compounds shall be completed within the maximum working times as follows; the application and working of caulking material shall be completed within 70% of the minimum "skin" time, considering application conditions. When two-part compounds are being used, only the amount of caulking that can be installed within 70% of the maximum recommended pot life shall be mixed.

L. Adjoining surfaces, finishes, and fixtures shall be carefully protected throughout caulking operations. Stains, marks, or damage as a result of caulking and sealing work shall be removed.

18.19: FLAMMABILITY, TOXICITY, AND SMOKE EMISSION

18.19.01. General

A. Materials used in the vehicle shall comply with the flammability, smoke emission, toxic gas and fire retardation requirements specified herein. Waivers may be requested for items with minimal combustible content, such as the natural rubber seals on brake valves.

B. Materials used in the vehicles shall be low halogen in addition to meeting the low-smoke requirements specified below.

C. As a minimum, all materials used in the construction of the vehicle shall meet the requirements of the 49 CFR 238.103, and Appendix B to Part 238 - Test Methods and Performance Criteria for the Flammability and Smoke Emission Characteristics of Materials Used in Passenger Cars and Locomotive Cabs. Unless otherwise specified below, all materials and construction shall meet the requirements of NFPA 130 - 2003, Table 8.4.

D. Should a conflict exist between the NFPA requirements, federal requirements and requirements listed elsewhere in these provisions, the more restrictive requirement shall govern.

E. The Contractor shall furnish a list of materials (flammability matrix) used in the vehicles showing location of material, weight (density and total weight), heat value per pound and per vehicle, flame spread, flashpoint, smoke generation and toxicity. [CDRL 18- 22]

F. The Contractor shall submit laboratory test results for each test, including a technical data sheet, for approval. [CDRL 18-23]

G. Test report documentation shall specifically identify the tested material by the same description that appears on the technical data sheet and other related references. This documentation must be directly traceable to the applicable carbuilder drawings without ambiguity.

H. Copies of prior test results showing that proposed materials have complied with the specified standards and tests may be submitted for approval. Assurance may be required that the material presently being considered for use is the same composition as that previously tested.

18.19.02. Flammability And Smoke Generation Criteria

Function of Material (numbers in parentheses indicate applicable notes below)	**Test Procedure**	**Performance Criteria**
All vehicle materials & components except as otherwise noted. (Wall Panels, Ceiling Panels, Partition Panels, Windscreens, Fiberglass, Plastics, Diaphragms, Non-sealing Elastomers, etc.) (1, 2, 9, 12)	ASTM E162 ASTM E662	$I_s \leq 35$ D_s (1.5) ≤ 100, D_s (4.0) ≤ 165
HVAC Ducting	ASTM E162	$I_s \leq 35$

Function of Material (numbers in parentheses indicate applicable notes below)	Test Procedure	Performance Criteria
(1, 2)	ASTM E662	D_s (4.0) ≤ 100
Lighting Diffusers / Plastic Glazing (2, 14)	ASTM E162 ASTM E662	I_s ≤ 100 D_s (1.5) ≤ 100, D_s (4.0) ≤ 200
Thermal and Acoustical Insulation (1, 2)	ASTM E162 ASTM E662	I_s ≤ 25 D_s (4.0) ≤ 100
Flexible Cellular Foams (1, 2, 4, 6)	ASTM D3675 ASTM E662	I_s ≤ 25 D_s (1.5) ≤ 100, D_s (4.0) ≤ 175
Elastomers – Lock strip gaskets (1, 2, 10, 11)	ASTM C542 ASTM E662	Pass criteria in table 1 D_s (1.5) ≤ 100, D_s (4.0) ≤ 200
Elastomers – Other gaskets or seals (1, 2, 10, 11)	ASTM C1166 ASTM E662	100mm (4.0 in), maximum flame propagation (15) D_s (1.5) ≤ 100, D_s (4.0) ≤ 200
Structural – Floor, Roof (16, 17, 18)	ASTM E119	Pass (30 Minutes minimum endurance at AW3 loading)
Floor Covering (12, 13)	ASTM E648 ASTM E662	CRF ≥ 0.5 W/cm^2 D_s (1.5) ≤100, D_s (4.0) ≤ 200
Seat Cushion, Mattresses (1, 2, 3, 4, 5, 6, 7, 8)	ASTM D3675 ASTM E662	I_s ≤ 25 D_s (1.5) ≤ 100, D_s (4.0) ≤ 175
Seat Frame, Seat Shroud (1, 2)	ASTM E162 ASTM E662	I_s ≤ 35 D_s (1.5) ≤ 100, D_s (4.0) ≤ 200
Upholstery (1, 2, 3, 6, 7, 8)	14 CFR (FAR) 25.853 (Appendix F, vertical, textiles) ASTM E662	Flame Time ≤ 10 sec. Burn Length ≤ 6 in (150 mm) D_s (4.0) ≤ 200
Wire Insulation (1, 2, 19)	IEEE Std 383 - Flammability ASTM E662	Pass D_s (4.0) ≤ 50

Numbered notes are based upon NFPA 130, and 49 CFR Appendix B to Part 238. These comments have been quoted, combined from both, or adapted/edited to passenger transit applications.
1) Materials tested for surface flammability shall not exhibit any flaming running or dripping unless an appropriate fire hazard analysis is conducted and approved by the Authority.
2) The ASTM E 662-97 maximum test limits for smoke emission (specific optical density) shall be measured in both the flaming or non-flaming mode, values shall be provided for both cases.

3)	Testing of a complete seat assembly (including cushions, fabric layers, upholstery) according to ASTM E1537 using the pass/fail criteria of California Technical Bulletin 133, and testing of a complete mattress assembly (including foam and ticking) according to ASTM E1590 using the pass/fail criteria of California Technical Bulletin 129 shall be permitted in lieu of the test methods prescribed herein, provided the assembly component units remain unchanged or new (replacement) assembly components possess equivalent fire performance properties to the original components tested. Testing shall be at 50 kW/m2 applied heat flux with a retainer frame. A fire hazard analysis must also be conducted that considers the operating environment within which the seat or mattress assembly will be used in relation to the risk of vandalism, puncture, cutting, or other acts which may expose the individual components of the assemblies to an ignition source. The requirements of Notes 5, 6, 7, and 8 shall be met.
4)	Testing is performed without upholstery.
5)	The surface flammability and smoke emission characteristics shall be demonstrated to be permanent after dynamic testing according to ASTM D3574, Test I 2 (Dynamic Fatigue Test by the Roller Shear at Constant Force) or Test I 3 (Dynamic Fatigue Test by Constant Force Pounding) both using Procedure B, except that the test samples shall be a minimum of 6 inches (154 mm) by 18 inches (457 mm) by the thickness of the material in its end use configuration, or multiples thereof. If Test I 3 is used, the size of the indentor described in paragraph 96.2 shall be modified to accommodate the specified test specimen.
6)	The surface flammability and smoke emission characteristics shall be demonstrated to be permanent by washing, if appropriate, according to FED-STD-191a Textile Test Method 5830.
7)	The surface flammability and smoke emission characteristics shall be demonstrated to be permanent by dry-cleaning, if appropriate, according to ASTM D2724-87.
8)	Materials that cannot be washed or dry-cleaned shall be so labeled and shall meet the applicable performance criteria after being cleaned as recommended by the manufacturer.
9)	As a minimum, all combustible materials used anywhere in the vehicle (except as noted in 10) are required to be tested including interior, cab components as well as exterior components. Combustible signage shall not be required to meet flame spread or smoke emission requirements if (a) the actual thickness of the signage is no greater than 1.5 mm (0.060 in.); (b) the aggregate area of combustible signage does not exceed 10 percent of the wall area of the car, including windows; and (c) no single sign is larger than 0.47 m2 (5.0 ft2). Items that can not be made compliant due to other dominating engineering requirements may not be required to meet the flammability or smoke emission performance criteria specified, but still must be tested to establish the relative risk and evaluated, and waived, by the Transit Authority.

10) Materials used to fabricate miscellaneous, discontinuous small parts (such as knobs, rollers, fasteners, clips, grommets, and small electrical parts) that will not contribute materially to fire growth in end use configuration are exempt from flammability and smoke emission performance requirements, provided that the surface area of any individual small part is less than 16 square inches (100 cm2) in end use configuration and an appropriate fire hazard analysis is conducted which addresses the location and quantity of the materials used, and the vulnerability of the materials to ignition and contribution to flame spread.
11) If the surface area of any individual small part is less than 16 square inches (100 cm^2) in end use configuration, materials used to fabricate such a part may be tested in accordance with ASTM E1354 as an alternative to both (a) the ASTM E162 flammability test procedure, or the appropriate flammability test procedure otherwise specified in the table, and (b) the ASTM E662 smoke generation test procedure. Testing shall be at 50 kW/m2 applied heat flux with a retainer frame. Materials tested in accordance with ASTM E1354 shall meet the following performance criteria: average heat release rate (qÿ´´ 180) less than or equal to 100 kW/m^2, and average specific extinction area (sf) less than or equal to 500 m^2/kg over the same 180-second period.
12) Carpeting used as a wall or ceiling covering shall be tested according to ASTM E162 and ASTM E662 and meet the respective criteria of I s less than or equal to 35 and D s (1.5) less than or equal to 100 and D s (4.0) less than or equal to 200. Notes 1 and 2 apply.
13) Floor covering shall be tested with padding in accordance with ASTM E648, if the padding is used in the actual installation.
14) For double window glazing, only the interior glazing is required to meet the requirements specified herein. (The exterior glazing is not required to meet these requirements.)
15) Average flame propagation shall be less than 4 inches and no specimen shall be completely consumed.
16) Penetrations (ducts, access openings, etc.) shall be designed against acting as passageways for fire and smoke and representative penetrations shall be included as part of test assemblies.
17) A structural flooring assembly separating the interior of a vehicle from its undercarriage shall meet the performance criteria during a nominal test period as determined by the railroad. The nominal test period must be twice the maximum expected time period under normal circumstances for a vehicle to stop completely and safely from its maximum operating speed, plus the time necessary to evacuate all the vehicle's occupants to a safe area. The nominal test period must not be less than 15 minutes. Only one specimen need be tested. A proportional reduction may be made in the dimensions of the specimen provided it serves to truly test the ability of the structural flooring assembly to perform as a barrier against under-

	vehicle fires. The fire resistance period required shall be consistent with the safe evacuation of a full load of passengers from the vehicle under worst-case conditions.
18)	Portions of the vehicle body which separate major ignition sources, energy sources, or sources of fuel-load from vehicle interiors, shall have sufficient fire endurance as determined by a fire hazard analysis acceptable to the railroad which addresses the location and quantity of the materials used, as well as vulnerability of the materials to ignition, flame spread, and smoke generation. These portions include equipment carrying portions of a vehicle's roof and the interior structure separating the levels of a bi-level car, but do not include a flooring assembly subject to Note 17.
19)	Testing shall be conducted in accordance with ANSI/IEEE Standard 383-1974, section 2.5, with the additional requirement that circuit integrity shall continue for 5 minutes after the start of the test.

18.19.03. Toxic Content Limits In Combustion Products

A. The maximum toxic gas concentration in the combustion products of any materials used in the construction of the vehicle shall not exceed the following values:

Toxic Gas – BSS-7239	**Maximum Concentration**
Carbon monoxide (CO)	3500 ppm
Hydrogen Fluoride (HF)	200 ppm
Nitrogen dioxide (NO2)	100 ppm
Hydrogen Chloride (HCL)	500 ppm
Hydrogen cyanide (HCN)	150ppm
Sulfur dioxide (SO2)	100 ppm

18.20: STRUCTURAL PANELS

18.20.01. General

A. Sandwich panels include, but are not limited to, plymetal, honeycomb, or lumber-core panels with metal or other approved facing material.

B. Composite structural panels include, but are not limited to, panels manufactured from reinforced polymer resins using a reinforcing core material. These panels are typically faced with a cosmetic material or sheet product to provide a complete assembly.

C. Sandwich panels shall be fully balanced in construction

D. Melamine coated high pressure laminates used in the construction of the vehicle shall be two-ply laminated and shall consist of a hard plastic film facing permanently bonded to base sheet.

1. Contact adhesives shall not be used to bond the melamine to the base.

2. The final laminate assembly shall comply with NEMA LD-3, General Purpose Type, and comply with the Flammability, Smoke Emission & Toxicity section of this Specification.

18.20.02. Honeycomb

A. When finished, continuous edge reinforcement shall be incorporated to facilitate transfer of stresses and to seal edges against moisture penetration and other damage. Where mechanical fasteners are used, threaded inserts shall be bonded into the panel.

B. The term honeycomb panel as used in these provisions refers to honeycomb material bonded to melamine or to metal in a heated press.

C. Bonding between the base material and the cover shall be sufficient to develop the full strength of the honeycomb material. The Contractor shall demonstrate by test and analysis that the honeycomb panel design, selected for a particular application, is adequate for the intended purpose.

18.20.03. Panel Flatness

A. The overall flatness shall not exceed a maximum deviation of 0.015" per lineal foot, with a maximum of 0.125” deviation of any point on the panel measured from a reference plane taken from any three corners. The overall deviation of the panel thickness shall not exceed 0.031" (1/32").

18.21: MOLD OWNERSHIP

A. All fabricating tooling, trimming devices, plug assists, vacuum boxes, and the like shall become the property of the Authority.

   1. The fabricator shall retain possession of the tooling but will clearly indicate on each item the proper owner.

   2. The fabricator shall be responsible for the care and condition of the tooling.

   3. The fabricator shall maintain theft and fire insurance on the tooling at no charge to the Authority.

   4. The fabricator shall return the tooling to the Authority if the processor moves, sells, goes out of business, or is requested to do so by the Authority.

B. The fabricator shall design such tooling as to ensure its ability to be used on like or other commercially popular equipment.

C. The fabricator shall refund the cost of all the tooling to the Authority should the tooling be determined to be non-interchangeable, lost, stolen, confiscated, or destroyed.

18.22: CLEANING AND PREPARATION

A. All debris resulting from cleaning of vehicle or components or from building operations shall be promptly removed; sandblast grit, scrap, shavings, insulation, fasteners, pipe, etc.

B. All compounds and liquids used in cleaning and preparation operations shall be promptly removed, and flushed if required, from the vehicle or the component.

C. Every effort shall be made to remove all debris from the vehicle at regular intervals to prevent same from becoming lodged in inaccessible areas of the vehicle assembly.

18.23: INSULATION

18.23.01. General

A. Insulating materials shall be fire-retardant, non-hygroscopic, resistant to fungus, and provided with a vapor barrier as required to prevent the entry of moisture, oil, gases, and dust.

B. The materials shall not absorb fluids and gases and shall possess the required properties to meet the noise and vibration requirements of this specification.

C. The method of insulation retention in the carshell, for all insulating materials, shall be subject to Authority approval.

D. The Contractor shall submit to the Authority for review and approval, data on thermal and acoustic insulation materials and their installation and application processes. [CDRL 18–24]

18.23.02. Acoustic Insulation

A. Sound damping material used in the fabrication of the vehicle shall be resistant to diluted acids, greases, gasoline, fuel oils, aliphatic oils, and vermin. Material must be resistant to fungus and must not support combustion. The material shall not be affected by sunlight or ozone, and shall not become brittle with age. Application shall be in accordance with the Supplier's recommendations.

18.23.03. Thermal Insulation

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

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

C. Urethane foam insulation is expressly prohibited.

D. Thermal insulation material shall have a thermal conductivity of not greater than 0.25 Btu/hr-ft2-F°/in (13,000 J/hr-m2-C°/cm) when tested in accordance with ASTM C177.

E. Insulation shall be integral with the vehicle construction. Insulating material exposed to view shall not be acceptable. Insulation and means of attachment within the vehicle structure shall be designed for a service life of no less than vehicle mid-life overhaul.

18.24: FIBERGLASS-REINFORCED PLASTIC

A. Fiberglass-reinforced plastic (FRP) shall be polymeric-reinforced laminated material, composed of a gel-coated surface, fiberglass reinforcement, and a polyester, acrylic, phenolic, or approved equal resin.

1. FRP shall be able to withstand, without any physical degradation or deformation, the stresses encountered in the environment where it is to be used. Fiberglass components shall be molded, stored and mounted in their final designed shape and shall not be mounted in a deformed/stressed condition.

2. FRP shall be resistant to acids, mild alkalis and cleaning solutions normally used in rail transit service.

3. FRP products shall meet the Flammability, Smoke Emission & Toxicity section of this specification.

4. Fiberglass reinforcement shall be mat, fabric, woven roving, continuous roving, chopped spun roving or swirl mat as required to meet physical and process requirements. Glass content of the finished component by weight shall be 30 percent minimum. Gelcoats shall be resistant to scuffing, fire, weather, perspiration and cleaning agents, and shall be pigmented to match approved colors. Gelcoat must contain UV inhibitors/stabilizers or be formulated to minimize any discernable yellowing or color degradation.

5. Gelcoat additives, fillers, monomers, catalysts, activators, inhibitors, pigments or flame proofing materials shall be added to resin mixes to obtain finished products with required characteristics. Mineral filler shall not exceed 28 percent of finished weight for preformed matched die molding process.

6. FRP shall be manufactured by one of the following methods:

   a. Method 1: Open molding, hand lay-up, or spray lay-up (Chopper Gun)

   b. Method 2: Matched die molding, RTM, VACuum bag or preform

7. Production techniques shall ensure that the fiberglass reinforcement is distributed throughout the final product in such a manner as to preclude resin-rich or resin-starved sections.

8. Open-molded parts shall be gelcoated.

9. Surfaces shall be uniform, smooth, and free of porosity and crazing.

B. The Contractor shall submit to the Authority for review and approval, certificates verifying that reinforced plastic materials comply with the minimum requirements specified below [CDRL 18-25]. Pre-test conditioning of test specimens shall conform to ASTM D618.

Mechanical Property	Test Method	Method #1	Method #2
Tensile Strength	ASTM D638	13,000 psi	18,000 psi
Compressive Strength	ASTM D695	22,000 psi	32,000 psi
Flexural Strength	ASTM D790	21,000 psi	28,000 psi
Impact	ASTM D256	10 ft-lbs/ in of notch	13 ft-lbs/ in of notch
Hardness	ASTM D2583	45 Barcol	45 Barcol
Heat	None	175°F Continuous	-
Thickness	None	0.125 in, minimum	0.125 in, minimum
Gelcoat Thickness	None	0.014” or 14 mils, ± 2 mils.	N/A

18.25: THERMOPLASTIC

A. Thermoforming plastic may be used, subject to Authority approval.

B. Thermoplastic materials shall comply the Flammability, Smoke Emission & Toxicity section of this specification, and with the following requirements:

Physical Property	Test Method	Performance Requirement Value
Specific Gravity	ASTM D792	1.20 to 1.36
Hardness, Rockwell	ASTM D785	90 to 100, R-Scale
Tensile Strength	ASTM D638	5,500 psi (38 MN/m^2) minimum at 73°F (23°C)
Flexural Modulus	ASTM D790	320,000 psi (2206 MN/ m^2) minimum elasticity at 73°F (23°C)
Flexural Strength	ASTM D790	10,000 psi (68,947.6 kPa) minimum @ 73°F (23°C)
Impact Strength (@ 73°F notched IZOD)	ASTM D256	6.6 foot pounds per inch of notch minimum.
Heat Shrinkage	None	15% maximum, 10 minutes @ 380°F (193°C)
Thickness	None	3/32 inch (2.38 mm) minimum

18.26: MARKING FILMS & GRAPHICS

A. All graphic materials shall be transportation grade materials. Signage graphics shall have an opaque background with clear, vandal resistant overlayment such as polyvinyl fluoride or polycarbonate. Printed signage graphics shall be either reverse printed on the back of the clear overlayment, or printed on opaque background and covered by the clear overlayment. The Authority shall approve all materials, graphic construction, and fixing method.

B. Application techniques shall be in accordance with manufacturer's recommendations.

18.26.02. Physical Properties of Graphic Material

A. Lettering or striping film shall be sufficiently opaque so that, when applied, the film shall completely hide any contrasting background and shall be readily legible.

B. There shall be an initial 60-degree gloss value of 40 when tested in accordance with ASTM D523.

C. Films shall retain adhesive properties after one week of continuous exposure to a temperature of 150°F (66°C).

D. Films shall be able to conform to moderate contours of the vehicle's interior and exterior surfaces at locations where applied.

E. Overall thickness of processed film shall be between 0.004” and 0.008” (0.10 mm and 0.20 mm), multiple layer graphics may be up to 0.020” in total thickness (excluding mounting adhesive thickness).

F. Films shall withstand immersion in either distilled water or SAE No. 20 motor oil for 24 hours at temperatures of from 70°F to 90°F (21°C to 32°C) without any appreciable degradation in adhesion, color, or general appearance.

G. Marking films shall withstand effects of detergents and brushes used in washing procedures for removal of graffiti.

H. Films shall use a removable grade adhesive that upon removal does not require use of solvents, or secondary operations to remove adhesive or graphic residue.

I. Square or rectangular graphics shall have rounded corners of suitable radius to prevent the lifting or curling of corners.

J. Graphic material used for vehicle striping shall be 3M 690 Plus Flexible Reflective Sheeting, removable grade or Authority approved equivalent.

18.26.03. Emergency Exit Signage

A. Emergency exit signage shall comply with APTA SS-PS-004-99, Standard for Low-Location Exit Path Marking and 49 CFR, Part 238.

B. Low Level Exit Path Marking (LLEPM) material shall be provided to illuminate the path to each emergency exit.

C. The LLEPM and emergency exit signage shall passive and independent of the car’s normal and emergency lighting systems.

1. High Performance Photo-luminescent (HPPL) material shall be used in the fabrication of the exit signage and the LLEPM.

D. The Contractor shall provide independent laboratory certified test result reports confirming that the HPPL material, complies with the minimum luminance criteria of 7.5 mcd/m2, after 1.5 hours, when tested according to the provisions of ASTM E-2073-02 Standard Test Method for Photopic Luminance of Photo-luminescent (Phosphorescent) Markings. [CDRL 18-26]

E. See TS 14, Interior/Exterior Appointments, for additional information.

18.26.04. Emergency Access Signage

A. Each door intended for use by emergency responders for rescue access shall be identified with emergency access signs and instructions consisting of retro-reflective materials.

B. Retro-reflective material shall be protected by the anti-graffiti coating applied to the exterior of the vehicle. Coating shall not deter from material reflective properties.

C. The Contractor shall provide certificates that ensure that retro-reflective material has been tested in to comply with ASTM E-810-03, Standard Test Method for specific intensity per unit area of Retro-reflective Sheeting. [CDRL 18-27]

18.27: FABRICS & UPHOLSTERY

A. Upholstery fabrics for vehicle seats shall be approved transportation-grade fabrics with backing. Fabric shall be able to be cleaned by at least three widely available commercial industrial cleaning agents that are known to be chemically compatible.

18.27.02. Woven Fabric

A. Woven upholstery fiber shall be worsted spun. Fiber content shall be 90 percent wool and 10 percent nylon. Fabric weight exclusive of backing shall be not less than 12.5 oz/yd2 (0.42 kg/m2). Maximum fabric shrinkage shall be 2 percent.

B. Woven seat upholstery shall meet the following standard test criteria:

Physical Property	Test Method	Requirement
Weight	ASTM D3776, Option B	12.5 oz/sq. yard
Fabric Construction	ASTM D3775	43 PPI
Tensile Strength	ASTM D5034	100 lbs. Warp 100 lbs. Fill
Tearing Strength (Tongue)	ASTM D2262, B3, Sec 7.2	Warp - 20 lbs Fill - 15 lbs.
Abrasion Resistance	ASTM D3884, Taber 500g, CS 10 Wheel	500 Cycles Minimum, No breaks

Crocking	ASTM D3597, Sec 7.9, (AATCC Method 16, Option E)	4.0 Dry 4.0 Wet
Pilling Resistance	ASTM D3512	Pass, level 4 (slight pilling)
Shrink Resistance	AATCC 99-2000	2% maximum
Light Fastness	ASTM D3597, Sec 7.10, 40 hrs	4@40 Hours
Seam Strength (sewing)	ASTM D1683, Sec 11.1	50 lbs.
Yarn Slippage (sewing)	ASTM D4034	Warp - 50 lbs Fill - 50 lbs.

18.27.03. Vinyl Fabric

A. Vinyl upholstery fabrics for vehicle seats shall be approved transportation-grade fabric with woven backing.

B. Seat Upholstery physical properties shall meet the following test criteria:

Physical Property	Requirement	Test Method
Total Weight	33.0 oz./yd @ 54"wide (linear yard)	CFFA-700D
Thickness	45 mils	CFFA-700C
Tensile Strength	65 lbs. (long direction) 60 lbs. (cross direction)	CFFA-17
Tearing Strength (Trapezoid)	14 lbs. (long direction) 12 lbs. (cross direction)	CFFA-16C
Coating Fabric Bond	3 lbs./in.	CFFA-3A
Stretch	5% (long direction) 25% (cross direction)	CFFA-15
Abrasion Resistance	a) No wear through skin @ 500 double rubs with 240-grit silicon-carbon cloth and b) No wear through skin @ 250,000 double rubs with #8 cotton duck	CFFA-1a Wyzenbeek
Crocking	Good-Minimum	CFFA-7, dry
Blocking	Scale Rating No.3 Maximum	CFFA-4
Cold Resistance	-20°F, No cracking	CFFA-6A, 5# roller
Accelerated Weathering Resistance Test	No fading, discoloration, or stiffness after 225.6 kJ	CFFA-2, A1, (SAE-J1885) B1, (ASTM G26 -A) C1, (ASTM D4329)

18.28: ELECTRICAL DEVICES AND HARDWARE

18.28.01. Contactors and Relays

A. All contactors and relays shall be service proven devices used in railroad applications. Contactors and relays shall meet or exceed IEC 60077. Low-current relays (less than 10 Amp per pole) shall have silver-alloy contacts. Very low current relays (1 Amp and less) shall have gold-plated, silver-alloy contacts. Relays and contactors that have not been proven in rail service shall comply with MIL-PRF-6106.

B. Devices shall be constructed in a heavy-duty fashion suitable for use in railroad service.

C. The coils of all devices shall be suppressed using an RC-network or solid state devices appropriately sized to protect against transients generated along the low voltage network.

D. Contact tip rating shall be rated for the worst condition of reduced surface contact which may result from tip misalignment during normal operation of the device.

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

F. The estimated lifespan of all contact tips shall not be less than 4 years. Relays shall be capable of at least one million electrical operations at rated contact capacity with the exception of those operating on the order of 1000 times per day being capable of at least ten million electrical operations at rated capacity.

G. All contactors shall be constructed so that the main contact tips make and break with a motion (wipe) that prevents deposits or pitting.

H. All contactors shall be built with series-fed blowout coils.

1. The Contractor shall demonstrate the ability of each contactor type to reliably interrupt current over the full design operating range.

I. All devices shall be readily identifiable by means of a permanent, durable marking strip giving the device circuit designation.

1. No identifications shall be obscured, or partially obscured by wire routing.

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

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

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

1. No pneumatic or mechanical time delay devices are permitted.

L. Where plug in relays are accepted, the relay shall be positively retained by means of a restraining clip or bar.

1. This device shall be captive, or rugged construction and shall be easily positioned for relay installation or removal without the need for special tools.

2. When the relay is removed, the retainer shall itself be retained so that it cannot come in contact with devices which may have exposed energized electrical circuits, and shall not interfere with the operation of any other device when in this position.

18.28.02. Switches

A. Switches shall be provided with a “keying” feature that prevents the body of the switch from rotating.

B. Non-rotary switches shall be mounted in a vertical position with the “up” position being “on”. No secondary mechanical means shall be utilized to achieve this.

C. Switches proposed shall have a record of successful rail transit applications..

18.28.03. Circuit Breakers

A. All circuit breakers provided shall be extremely rugged and fully suitable for the service intended.

B. They shall be of the highest quality procurable.

C. All circuit breakers of the same rating shall be of the same manufacturer and model, throughout the vehicle.

D. The “on”, “off” and “tripped” positions of all circuit breakers shall be permanently marked on the handle, or prominently on the case of the circuit breaker.

  1. The circuit breaker, when tripped, shall assume a distinct position between the “on” and “off” positions.

  2. Circuit breaker handles shall protrude from the circuit breaker panel covers sufficiently to be operational in all positions.

E. Circuit breakers shall be individually replaceable without disconnecting or removing anything other than the mounting fasteners and electrical connections of the breaker.

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

  1. Wires to circuit breaker studs shall use ring terminals.

G. Circuit breaker terminals shall not be used as junction points.

H. Each and every power circuit shall be protected by an individual circuit breaker. No circuit breaker shall protect more than one circuit, nor shall any one circuit be protected by more than one circuit breaker.

I. All circuit breakers shall be sized by current rating and tripping time to protect both the associated equipment and the minimum size wire.

J. High voltage circuit breaker poles may be connected in series, if necessary, to achieve the stated voltage interruption requirements.

K. Each circuit breaker pole shall be equipped with adequate means of arc extinction to prevent flashover.

L. The continuous rating of magnetic trip circuit breakers shall be selected in accordance with ANSI/IEEE C37.16-2000 for the load and type of service specified.

M. All thermal-magnetic trip circuit breakers shall conform to the requirements of ANSI/ IEEE C37.13-1990 and ANSI/ IEEE C37.14-1979.

N. Circuit breaker current rating shall be clearly and permanently marked and shall be completely visible after installation.

O. Electrically operating circuit breakers shall be arranged for operation from low voltage DC power.

P. All circuits operated above 125V shall be considered high voltage.

Q. AC circuit breakers shall match the interruption capacity to the source.

R. Each high voltage circuit breaker shall have thermal magnetic or magnetic type trip elements connected in series.

S. Each low voltage circuit breaker shall be either one or two pole devices depending upon the intended function.

T. All high voltage DC circuit breakers shall be devices with not less than three poles connected in series.

U. The Contractor shall submit a comprehensive list of suggested fuses and circuit breakers to the Authority for review and approval. [CDRL 18-28]

V. Circuit breakers shall not be supplied to act in place of a switch.

W. All 230 VAC and 120 VAC circuit breakers shall be of a high shock-resistant design suitable for railway service.

18.28.04. Fuses

A. Fuses shall be used only where specified, or where the use of a circuit breaker is not technically feasible. Fuse applications not specifically approved in the CDRL above shall not be accepted.

B. Each fuse shall be permanently identified and readily accessible.

   1. The rating of each fuse shall be clearly and permanently marked on the fuse and holder.

C. The fuse holder shall have fuse retention devices at both ends.

D. Air gap and creepage distances shall be suitable for the application and as approved. Fuses used in nominal 600 VDC circuits shall be rated for no less than 1,000 VDC.

E. Each fuse compartment shall have a spare fuse of identical size and rating as the "in-circuit" fuse. This requirement shall not apply to the collector shoe fuse.

   1. The spare fuse shall be mounted in a convenient location and marked "spare".

F. Blown fuse indication shall be provided.

18.28.05. Bus Bars

A. Bus bars shall conform to the requirements of IEEE Std 16-2004.

B. Bus bars shall be fabricated from UNS number C10100, C10200, or C11000 copper, conforming to ASTM B187 as necessary.

C. Current densities, other than at joints, shall not exceed 2000 amperes per square inch, and in any case shall not exceed a value which would cause a bus bar temperature rise greater than 40 degrees C above ambient.

D. Current densities in joints shall not exceed 150 amperes per square inch.

E. Bus bar joints shall be silver or electro-tin plated.

F. Bus bar shall be properly brazed together at joints, unless bolted connections are found to be absolutely necessary for maintenance purposes, and are specifically accepted by the Authority.

G. The overlap at bus bar joints shall be no less than ten times the thickness of the bus material.

H. Bus bar connection bolts shall be torqued to obtain a uniform bus bar connection pressure of 200 psi.

I. Bolting hardware shall be plated steel with Belleville washers, or equivalent, to maintain connection pressure.

J. Except for connection areas, bus bars shall be safety-insulated, using a high-dielectric, powder coating or accepted means.

   1. Tape is not acceptable.

   2. Bus bars that are behind insulation panels are exempt from this requirement.

18.28.06. Capacitors and Resistors

A. Hermetically sealed, dry tantalum capacitors, in metal cases, shall be used in place of aluminum electrolytic capacitors, except for very high values which are not commercially practical or available. For these cases, long life grade aluminum electrolytic capacitors shall be used.

B. Commutating capacitors shall be a paper or plastic film type, shall incorporate a non-toxic impregnant, and shall be chosen to provide a service life of at least twenty years.

C. Filter capacitors shall have high ripple current rating for long life.

D. Capacitors shall be de-rated 20% for voltage based on nominal supply voltage and maximum case temperature.

E. If filter capacitors are exposed to low ripple voltages, lesser filter values of de-rating may be accepted if it can be shown that reduced operating temperatures can be achieved due to lower dissipation. The sum of the dc and ac ripple voltages shall always be less than the capacitor's voltage rating at a maximum case temperature of 85 degrees C.

F. Except for braking power resistors, all resistors shall be de-rated 50% for power dissipation.

G. Other power resistor applications may be submitted for acceptance of lower de-rating, on a case-by-case basis.

H. Fixed value type resistors shall be provided.

1. Calibration shall not require adjustable resistor or trimming potentiometers.

18.28.07. Transformers and Inductors

A. Transformers and inductors shall be de-rated 10 % for current. Transformers shall:

1. Have vacuum-impregnated windings.

2. Be rated to withstand at least twice the maximum peak-to-peak voltage that they shall be subjected to in operation.

3. Not emit audible noise in excess of 60 dB referenced to twenty micropascals at a distance of two feet while operating at rated voltage and load.

4. Be designed to minimize radiated and induced EMI.

5. Be located, orientated and mounted with cable connections and routing in accordance with the overall EMI/EMC control plan for the vehicle.

18.28.08. Switch, Circuit Breaker, and Fuse Panels

A. All switch, circuit breaker and fuse panels shall be dead front types mounted in specified equipment enclosures.

B. Each switch and circuit breaker panel shall carry the necessary apparatus, arranged to be easily accessible to connections and designed to prevent operating or maintenance personnel from coming in contact with live parts when operating the switches or circuit breakers.

C. All live portions of the protected circuitry shall be completely concealed so that no danger of electrocution or shock exists from the touching of the panel or any appurtenances or devices mounted thereto.

D. All switches, circuit breakers, fuses, and indicating lights shall be provided with a nameplate of raised or recessed lettering on the "dead front", clearly identifying the circuit which each controls and its circuit designation.

E. The "dead front" panel shall conform to NFPA 70, Article 408.

F. The "dead fronts" shall be made of moisture-proof, electrically insulating, laminated phenolic or fiberglass, of accepted quality suitable for switchboards. Asbestos shall not be used.

G. A wiring gutter shall be provided along the top, sides, and bottom, for the routing of high voltage leads to their designated circuit breakers.

H. The panel shall be secured by accepted, captive fasteners and shall be configured for easy removal so maintenance and repair action is not impeded.

1. Power distribution to the switches and circuit breakers shall be from a bus bar or bus circuit.

2. Distributing power by successive or “daisy-chained” connections between device terminals shall not be permitted.

18.28.09. Battery Backup circuits

A. Backup batteries shall not be permitted, unless specifically approved by the Authority.

18.28.10. Illuminated Status Indicators and Annunciators

A. All illuminated status indicators, annunciators or similar devices shall be long-life Light Emitting Diode (LED) type lamps, rather than incandescent bulbs.

18.28.11. Rotating Equipment

A. Rotating machinery shall be suitable for continuous duty, and the continuous duty shall be confirmed in accordance with IEEE Std 11-2000.

18.29: ELECTRONICS

18.29.01. Semiconductors

A. The Contractor shall be responsible for ensuring that all electrical and electronic circuitry, whether of his own design and manufacture or of those of his Manufacturers and Suppliers, shall meet, as a minimum, the criteria listed in this section.

B. Semiconductors for electronic circuits shall be adequately rated, including current rating, power rating, and Peak Inverse Voltage (PIV) rating and performance characteristics for the application intended.

C. Each discrete semiconductor shall have the following minimum voltage breakdown rating:

1. Transistors and thyristors operated from the nominal battery supply, or those connected to trainlines, shall have minimum breakdown ratings of 4 times the maximum circuit voltage.

2. All discrete semiconductors operated from inverters or other isolating devices shall have a minimum breakdown rating of 2 times the maximum circuit voltage, except where specifically detailed otherwise.

3. Suppression devices shall be provided, as necessary, to protect the device and limit the circuit voltage.

4. Diodes operated from the nominal battery supply used as suppression devices, or those connected to trainlines, shall have a minimum breakdown rating (PIV) of 1000 volts.

D. All semiconductors/integrated circuits shall be rated to properly perform in the temperature ranges specified by EN 50155-1995 for Class T3 equipment unless otherwise specified.

E. All semiconductor junction temperatures shall be limited to 80% of the maximum rated temperature for the device or less at maximum ambient temperature and at maximum rated output power.

F. All semiconductors 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. High power/current devices may be exempt from this requirement with prior approval on a case-by-case basis.

G. The Contractor shall submit complete device information, including all manufacturers' application recommendations, and calculated current and power demands with all waiver requests. If approved, such waivers shall not reduce other requirements, including reliability.

H. Circuits shall be designed to limit excessive current to semi-conductors, to prevent damage from high discharges (spikes) and to limit excessive temperature through properly designed heat sinks, where required.

I. Ventilation for cooling shall not pass ambient air over areas of voltage stress.

J. Integrated circuits operated from the battery supply through inverter or other isolated devices shall be operated within the voltage and current ratings specified by the manufacturer, de-rated to less then 50 percent of the maximum stress level at the maximum operating temperature of the device, as specified by the manufacturer.

1. Where the supply to integrated circuits is regulated and surge protected, the voltage rating shall be 15 percent below the manufacturer's recommended maximum.

2. In addition, the maximum power shall be limited to 50 percent of the manufacturer's specified maximum at the maximum operating temperature.

K. All semiconductors shall be JEDEC registered and numbered, and shall be available from at least two different manufacturers unless otherwise approved by the Authority. Non-JEDEC registered devices which carry more than 10 Amps may be used with prior approval, based on submission of complete procurement specifications defining each such device and evidence of availability from two or more manufacturers.

L. All integrated circuits shall be burned in and screened for defects to a level equivalent to MIL-STD-883, method 5004, reliability class B.

1. Alternate methods based on a minimum 100 hour burn-in for the completed assembly shall be considered.

    a. The burn-in shall be performed with the equipment operational (power on), with the necessary input signals and loads to simulate the maximum power dissipating conditions in the device, and with functional monitoring to identify intermittent malfunctions.

M. Matching of components is permitted only if the components are normally available from the manufacturer in matched sets.

N. Germanium semiconductors shall not be utilized.

18.30: ELECTRICAL AND ELECTRONIC DESIGN

18.30.01. General

A. All computer hardware and software to be provided under this Contract is subject to the requirements provided in this section and TS 17, Software Systems.

B. Except as otherwise noted herein, electronic equipment shall conform to IEEE Std 16-2004 and EN 50155 (including section 6.1), unless otherwise approved by Authority. All type tests shall be performed.

C. Unless specified otherwise in other sections of this specification, all semiconductors shall be operated at less than 50% of their maximum current or power rating. The more restrictive rating shall apply.

D. Unless otherwise specified or approved, all semiconductors shall be rated for operation between -13°F and 185°F (-25^{o} C and 85^{o} C).

E. The design of optical fiber connections must be submitted for review and acceptance by the Authority. The purpose of this review is not to discourage the use of optical fiber but to ensure the reliability and maintainability of the application. Connections between optical fibers and line replaceable units shall be via approved quick disconnects.

F. Soldered interconnections and assemblies shall comply with IPC J-STD-001, and IPC-HDBK-001 criteria considering strength, fatigue susceptibility, and durability.

18.30.02. Printed Circuit Boards

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

B. Printed circuit boards shall be designed to IPC-2220 (series), latest revision, except where more stringent requirements are noted herein. Printed circuit boards supplied under this Specification shall be Class 2, minimum, with the exception of wayside computers that are not utilized in vehicle operation. Class 3 requirements shall apply to all vital equipment.

C. Circuit board material shall be per NEMA Standard LI 1, Type FR-5.

D. Printed circuit boards shall have a minimum thickness of 1/16-in. base material.

E. All conductor material shall be copper, shall be firmly attached to the board and shall be resistant to blistering and peeling when heated with a soldering iron.

F. All printed circuit boards shall meet the requirements of IPC-A-610 revision D.

G. Traces shall be made as wide as practical, with the minimum width being based on a 10 degree C temperature rise.

H. All circuit boards shall be labeled with a part number, serial number, and descriptive nomenclature.

1. The component and wiring sides of the board shall each be marked to indicate capacitor and diode polarity, and at least two leads or one lead and a graphic symbol indicating orientation of all transistors and thyristors.

2. Integrated circuits and other multi-terminal devices shall have an index mark on the component side of the board, visible with the component inserted, to indicate proper keying and insertion; additionally, the first pin on all IC packages shall be identified on the wiring side of the board.

3. The labels used to identify components on the printed circuit board shall match those used in the schematic drawings for that particular component.

I. Components shall be fastened to the board in such a manner as to withstand repeated exposure to shock and vibration.

J. Circuit boards shall be inherently stiff or shall be reinforced to prevent damage due to vibration or handling.

K. Sufficient clearance shall be provided between components to allow testing and replacement without difficulty.

L. Both sides of the assembled printed circuit boards shall be coated with a clear insulating and protective coating material conforming to IPC-HDBK-830, Class 2, or approved equal.

1. The coating shall be easily removed with a brush-applied solvent or penetrated by a hot soldering iron when a component must be unsoldered.

2. The coating solvent shall not adversely affect board-mounted components.

3. All IC sockets, connectors, and test points shall be masked when the coating is applied.

M. Provision shall be made on each printed circuit board for “keying” to prevent insertion into the wrong socket. Circuit boards in safety related systems and subsystems shall be interlocked through a safety circuit to disable the vehicle, if a circuit board is removed.

N. Printed circuit board connectors shall be a heavy duty, high reliability, two-part type with a history of successful service in rail applications and shall be reviewed and approved by the Authority prior to commencing design. [CDRL 18-29]

1. Connectors which comply with MIL-DTL-55302 or EN 60603 Level 1 or 2 and which have plated contacts as described below are considered to comply with the requirements of this Section.

    (1) The connector contact area shall be plated with a minimum of 0.000030 in. of gold over a minimum of 0.000050 in. of low stress nickel.

2. Card-edge connectors are prohibited.

3. Wire wrap connections shall not be used unless specifically accepted by the Authority.

O. Test jacks shall be provided in appropriate locations on modules and printed circuit boards in sufficient quantity to localize fault isolation to the lowest replaceable assembly (e.g. PC board, input, wiring grounds).

1. A negative return test point shall be provided.

2. Each test point shall accept and hold a standard 0.080 in. diameter tip plug and shall be identified by appropriate markings.

P. Printed circuit boards and modules shall be positively retained by means of keeper bars or similar means.

1. Keeper bars shall be retained by chains or links to prevent loss when removed to allow change-out of circuit boards.

2. The use of tools shall not be required to remove or replace the keeper bars.

Q. Except for ICs, plug-in components shall be retained with a retaining device.

R. The use of multi-layer PC boards shall be submitted for review and acceptance by the Authority.

S. All printed circuit boards with the same function shall be interchangeable between equipment groups without additional adjustment.

T. Circuit boards shall be designed to eliminate susceptibility to electrostatic discharge.

U. The use of jumper wires shall be minimized and shall not be used without the prior acceptance of the Authority.

V. Mounting arrangement of components on printed circuit boards is subject to Authority acceptance.

W. Large components shall be provided with support in addition to solder connections.

X. Power resistors shall be mounted on standoffs so that the resistor bodies do not contact the board, and shall be spaced far enough away from the board so that heat from the resistor shall not discolor or damage the board.

Y. Components shall be fastened to the board in such a manner as to withstand repeated exposure to shock and vibration.

Z. Printed circuit boards shall be designed for insertion and removal with power applied, except where power is removed by a switch adjacent to the card rack and except where the mechanical construction would generally prohibit removal and insertion with power applied. Where a switch is used, it shall be labeled with a warning regarding its proper use.

AA. Printed circuit boards that do not fully comply with these requirements, but have been specifically designed for and service proven in transit environments may be proposed for Authority consideration.

18.31: CDRL ITEMS REFERENCED

CDRL 18-01, “Material Records”, (Ref: TS 18.01.02.B)

CDRL 18-02, “MSDS/TSDS Submittal”, (Ref: 18.01.06.A)

CDRL 18-03, “Fastener Usage List”, (Ref: 18.03.01.I)

CDRL 18-04, “Structural Stainless Steel Test and Inspection Plan”, (Ref: 18.04.01.B)

CDRL 18-05, “HSLA Certificates”, (Ref: 18.05.01.B)

CDRL 18-06, “Heat Treated HSLA Certification”, (Ref: 18.05.01.C)

CDRL 18-07, “Casting Sample Reports”, (Ref: 18.06.01.H)

CDRL 18-08, “Casting Yield, Tensile and Charpy Results”, (Ref: 18.06.02.D)

CDRL 18-09, “Piping, Tubing and Pressure Vessel Spec. and Data”, (Ref: 18.11.01.G)

CDRL 18-10, “Piping Flushing and Cleaning Procedures”, (Ref: 18.11.02.L)

CDRL 18-11, “Wire Samples and Specifications”. (Ref: 18.12.01.I)

CDRL 18-12, “Wire Marking System Submittal”. (Ref: 18.13.04.A)

CDRL 18-13, “Sample Wire Markings”, (Ref: 18.13.04.I)

CDRL 18-14, “Records of Welder Qualification Tests”, (Ref: 18.16.02.C)

CDRL 18-15, “Weld Integrity Test Procedure”, (Ref: 18.16.02.E)

CDRL 18-16, “Welding Procedures”, (Ref: 18.16.12.B)

CDRL 18-17, “Resistance Welding Schedule”, (Ref: 18.16.12.C)

CDRL 18-18, “Corrosion Control Plan”, (Ref: 18.17.A.4)

CDRL 18-19, “Painting Procedure”, (Ref: 18.18.02.A)

CDRL 18-20, “Paint, Primer and Application Data”, (Ref: 18.18.02.A.1)

CDRL 18-21, “Adhesive List and Data”, (Ref: 18.18.04.B)

CDRL 18-22, “Flammability Matrix”, (Ref: 18.19.01.E)

CDRL 18-23, “Smoke, Flame and Toxicity Test Results”, (Ref: 18.19.01.F)

CDRL 18-24, “Insulation Data”, (Ref: 18.23.01.D)

CDRL 18-25, “Reinforced Plastic Certification”, (Ref: 18.24.B)

CDRL 18-26, "HPPL Material Luminance", (Ref: 18.26.03.D)

CDRL 18-27, "Retroreflective Sheeting Intensity", (Ref: 18.26.04.C)

CDRL 18-28, “Circuit Breakers and Fuses List”, (Ref: 18.28.03.U)

CDRL 18-29, “Printed Circuit Board Connections”, (Ref: 18.30.02N)

18.32: REFERENCES

18.32.01. Standards Referenced

14 CFR part 25, Airworthiness Standards: Transport Category Airplanes

29 CFR part 1910, Occupational Safety and Health Administration, Department of Labor

40 CFR part 82, Stratospheric Ozone Protection Rule (Environmental Protection Agency)

49 CFR 223, Safety Glazing Standards - Locomotives, Passenger Cars and Cabooses

49 CFR 238, Passenger Equipment Safety Standards

AA, Aluminum Association Standards for Aluminum Mill Products

AAR RP-585, Wiring and Cable Specification.

AAR RP-587, Wire and Cable Insulating Material—Silicone Rubber Insulated.

AAR Standard S 501, Specification for Wire and Cables

AATCC 99-2000, Dimensional Change of Woven or Knitted Textiles: Relaxation, Consolidation, and Felting

ANSI B1.1, Unified Inch Screw Threads (UN and UNR Thread Form) (AKA ASME B1.1)

ANSI B18.1.2, Square and Hex Bolts and Screws Inch Series (AKA ASME B18.1.2)

ANSI C37, (IEEE C37) Standard for Low-Voltage AC Power Circuit Breakers used in Enclosures

ANSI S1.11, Specifications for Octave-Band and Fractional-Octave-Band Analog and Digital Filters

ANSI Z26.1, Safety Code for Safety Glazing Materials for Glazing Motor Vehicles Operating on Land Highways

ANSI Z400.1, Hazardous Industrial Chemicals - Material Safety Data Sheets - Preparation

APA PS1-95, National Institute of Standards and Technology

APTA RP-E-002, Recommended Practice for Wiring of Passenger Equipment.

APTA RP-E-004, Recommended Practice for Gap and Creepage Distance.

APTA RP-E-009-98, Recommended Practice for Wire Used on Passenger Rolling Stock.

APTA SS-C&S-004-98, Standard for Austenitic Stainless Steel for Railroad Passenger Equipment

APTA SS-C&S-015-98, Standard for Aluminum and Aluminum Alloys for Passenger Equipment Car Body Construction

APTA SS-E-005-98, Standard for Grounding and Bonding.

APTA SS-PS-004-99, Standard for Low-Location Exit Path Marking

ASME, Pressure Vessel Code

ASME B31.1, Power Piping

ASTM A53, Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless

ASTM A123, Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products

ASTM A242, Standard Specification for High-Strength Low-Alloy Structural Steel

ASTM A262, Standard Practices for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steels

ASTM A269, Standard Specification for Seamless and Welded Austenitic Stainless Steel Tubing for General Service

ASTM A515, Standard Specification for Pressure Vessel Plates, Carbon Steel, for Intermediate- and Higher-Temperature Service

ASTM A516, Standard Specification for Pressure Vessel Plates, Carbon Steel, for Moderate-and Lower-Temperature Service

ASTM A568, Standard Specification for Steel, Sheet, Carbon, and High-Strength, Low-Alloy, Hot-Rolled and Cold-Rolled, General Requirements for

ASTM A588, Standard Specification for High-Strength Low-Alloy Structural Steel With 50 Ksi Minimum Yield Point to 4 In. Thick

ASTM A606, Standard Specification for Steel, Sheet, and Strip, High-Strength, Low-Alloy, Hot-Rolled, and Cold-Rolled, With Improved Atmospheric Corrosion Resistance

ASTM A666, Standard Specification for Austenitic Stainless Steel Sheet, Strip, Plate, and Flat Bar

ASTM B26, Aluminum-Alloy Sand Castings

ASTM B33, Specification for Tinned Soft or Annealed Copper Wire for Electrical Purposes

ASTM B85, Aluminum-Alloy Die Castings

ASTM B88, Standard Specification for Seamless Copper Water Tube

ASTM B108, Aluminum-Alloy Permanent Mold Castings

ASTM B187 / B187M - 06, Standard Specification for Copper, Bus Bar, Rod, and Shapes and General Purpose Rod, Bar, and Shapes.

ASTM B221, Standard Specification for Aluminum and Aluminum-Alloy Extruded Bars, Rods, Wire, Profiles, and Tubes

ASTM B456, Standard Specification for Electrodeposited Coatings of Copper Plus Nickel Plus Chromium and Nickel Plus Chromium

ASTM B633, Standard Specification for Electrodeposited Coatings of Zinc on Iron and Steel

ASTM C177, Standard Test Method for Steady-State Heat Flux Measurements and Thermal Transmission Properties by Means of the Guarded-Hot-Plate Apparatus (Supersedes ANSI Z98.1)

ASTM C542, Specification for Lock-Strip Gaskets

ASTM C1036, Standard Specification for Flat Glass

ASTM C1048, Standard Specification for Heat-Treated Flat Glass - Kind HS, Kind FT Coated, and Uncoated Glass

ASTM C1166, Standard Test Method for Flame Propagation of Dense and Cellular Elastomeric Gaskets and Accessories

ASTM C1422, Standard Specification for Chemically Strengthened Flat Glass

ASTM D395, Standard Test Methods for Rubber Property-Compression Set

ASTM D412, Standard Test Methods for Vulcanized Rubber and Thermoplastic Rubbers and Thermoplastic Elastomers-Tension

ASTM D471, Standard Test Method for Rubber Property-Effect of Liquids

ASTM D523, Standard Test Methods for Specular Gloss

ASTM D573, Standard Test Method for Rubber-Deterioration in an Air Oven

ASTM D618, Standard Practice for Conditioning Plastics for Testing

ASTM D624, Standard Test Method for Tear Strength of Conventional Vulcanized Rubber and Thermoplastic Elastomers

ASTM D638, Standard Test Method for Tensile Properties of Plastics

ASTM D695, Standard Test Method for Compressive Properties of Rigid Plastics

ASTM D746, Standard Test Method for Brittleness Temperature of Plastics and Elastomers by Impact

ASTM D785, Standard Test Method for Rockwell Hardness of Plastics and Electrical Insulating Materials

ASTM D790, Standard Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials

ASTM D792, Standard Test Methods for Density and Specific Gravity (Relative Density) of Plastics by Displacement

ASTM D1149, Standard Test Method for Rubber Deterioration-Surface Ozone Cracking in a Chamber

ASTM D1683, Test Method for Failure in Sewn Seam of Woven Fabrics

ASTM D2240, Standard Test Method for Rubber Property Durometer Hardness

ASTM D2244, Standard Practice for Calculation of Color Tolerances and Color Differences from Instrumentally Measured Color Coordinates

ASTM D2262, Test Method for Tearing Strength of Woven Fabrics by the Tongue (Single Rip) Method (Constant-Rate-of-Traverse Tensile Testing Machine)

ASTM D256, Standard Test Methods for Determining the Izod Pendulum Impact Resistance of Plastics

ASTM D2583, Standard Test Method for Indentation Hardness of Rigid Plastics by Means of a Barcol Impressor

ASTM D2651, Standard Guide for Preparation of Metal Surfaces for Adhesive Bonding

ASTM D2724, Standard Test Methods for Bonded, Fused, and Laminated Apparel Fabrics

ASTM D3359, Standard Test Methods for Measuring Adhesion by Tape Test

ASTM D3512, Standard Test Method for Pilling Resistance and Other Related Surface Changes of Textile Fabrics: Random Tumble Pilling Tester

ASTM D3574, Standard Test Methods for Flexible Cellular Materials—Slab, Bonded, and Molded Urethane Foams

ASTM D3597, Standard Specification for Woven Upholstery Fabrics-Plain, Tufted, or Flocked

ASTM D3675, Standard Test Methods for Surface Flammability of Flexible Cellular Materials Using a Radiant Heat Energy Source

ASTM D3775, Standard Test Method for Fabric Count of Woven Fabric

ASTM D3776, Standard Test Methods for Mass Per Unit Area (Weight) of Fabric

ASTM D3884, Standard Guide for Abrasion Resistance of Textile Fabrics (Rotary Platform, Double-Head Method)

ASTM D4034, Standard Test Method for Resistance to Yarn Slippage at the Sewn Seam in Woven Upholstery Fabrics

ASTM D4329, Standard Practice for Fluorescent UV Exposure of Plastics

ASTM D5034, Standard Test Method for Breaking Strength and Elongation of Textile Fabrics (Grab Test)

ASTM E119, Standard Test Methods for Fire Tests of Building Construction and Materials

ASTM E162, Standard Test Methods for Surface Flammability of Materials Using a Radiant Heat Energy Source

ASTM E165, Standard Test Method for Liquid Penetrant Examination

ASTM E446, Standard Reference Radiographs for Steel Castings Up to 2 in. (51 mm) in Thickness

ASTM E424, Standard Test Methods for Solar Energy Transmittance and Reflectance (Terrestrial) of Sheet Materials

ASTM E648, Standard Test Methods for Critical Radiant Flux of Floor-Covering Systems Using a Radiant Heat Energy Source

ASTM E662, Standard Test Methods for Specific Optical Density of Smoke Generated by Sold Materials

ASTM E1354, Standard Test Method for Heat and Visible Smoke Release Rates for

Materials and Products Using An Oxygen Consumption Calorimeter

ASTM E1537, Standard Test Method for Fire Testing of Upholstered Furniture

ASTM F519, Standard Test Method for Mechanical Hydrogen Embrittlement Evaluation of Plating Processes and Service Environments

ASTM F606, Standard Test Methods for Determining the Mechanical Properties of Externally and Internally Threaded Fasteners, Washers, and Rivets [Metric]

ASTM G26, Included in ASTM G155 - 05a Standard Practice for Operating Xenon Arc Light Apparatus for Exposure of Non-Metallic Materials,

BSS-7239, Test Method for Toxic Gas Generation From Materials on Combustion

CFFA-15, Stretch And Set

CFFA-16C, Tearing Strength

CFFA-17, Tensile Strength And Elongation

CFFA-1A, Abrasion Resistance

CFFA-2, Accelerated Light Aging

CFFA-3A, Adhesion Of Coating To Fabric

CFFA-4, Blocking

CFFA-6A, Cold Crack Resistance

CFFA-7, Crocking Resistance

CFFA-700, Dimensions of Coated Fabric

EN 50155, Electronic equipment on rail vehicles.

EN 60603, Connectors.

ICEA-S-66-524, Crosslinked Polyethylene Insulated Wire and Cable for Transmission and Distribution of Electrical Energy.

IEC 60077, Rules for Electric Traction Equipment

(This is a 5 part standard)

IEC 60571, Electronic Equipment Used On Rail Vehicles

IEEE 11, Rotating Electric Machinery For Rail And Road Vehicles

IEEE 16, IEEE Standard for Electrical and Electronic Control Apparatus on Rail Vehicles

IEEE 383, Type Test for Class 1E Electric Cables, Field Splices, and Connections

IPC J-STD-001, Requirements for Soldered Electrical and Electronic Assemblies.

IPC-2220 (series), Design Standards for Printed Circuit Boards.

IPC-A-610D -, Acceptability of Electronic Assemblies.

IPC-HDBK-001, Handbook and Guide to the Requirements for Soldered Electrical and Electronic Assemblies to Supplement ANSI/J-STD-001B.

IPC-HDBK-830, Guidelines for Design, Selection and Application of Conformal Coatings.

ISO 3506, Mechanical Properties Of Corrosion Resistant Stainless-Steel Fasteners

ISO 4042, Threaded Components - Electroplated Coatings

ISO 898, Mechanical Properties Of Fasteners Made Of Carbon Steel And Alloy Steel

MIL-A-9067, Adhesive Bonding Process And Inspection Requirements For

MIL-C-7438, Core Material, Aluminum, for Sandwich Construction

MIL-DTL-55302, Connectors, Printed Circuit, Subassembly and Accessories.

MIL-HDBK-349, Manufacture and Inspection of Adhesive Bonded, Aluminum Honeycomb Sandwich Assemblies for Aircraft

MIL-HDBK-691B, Adhesive Bonding

MIL-P-23469, Pin-Rivet, Grooved And Collar, Grooved Pin-Rivet, Swage-Locked (Lockpin) General Specification For

MIL-PRF-6106, Relays, Electromagnetic, Including Established Reliability Types

MIL-STD-883, Test Method Standard, Microcircuits

MIL-STD-889, Dissimilar Metals

MIL-W-22759/10B, Wire, Electrical, Fluorocarbon Insulated, Abrasion Resistant, Extruded PTFE, Nickel Coated Copper Conductor, 1000 Volt.

MIL-W-22759/6B, Wire, Electrical, Fluorocarbon Insulated, Abrasion Resistant, Extruded PTFE, Nickel Coated Copper Conductor, 600 Volt.

MIL-W-81381B, Wire, Electric, Polyimide Insulated, Copper or Copper Alloy

MIL-W-81044, Wire, Electric, Crosslinked Polyalkene, Crosslinked Alkine-Imide Polymer, or Polyarylene Insulated, Copper or Copper Alloy

NFPA 130, Standard for Fixed Guideway Transit Systems

NFPA 70 (NEC), National Electrical Code

SAE J403, Chemical Compositions of SAE Carbon Steels

SAE J429, Mechanical and Material Requirements for Externally Threaded Fasteners

SAE J673, Automotive Safety Glass

SAE J995, Mechanical and Material Requirements for Steel Nuts

SAE J1199, Mechanical and Material Requirements for Metric Externally Threaded Fasteners

SAE J1200, Blind Rivets~Break Mandrel Type

SAE J1885, Accelerated Exposure of Automotive Interior Trim Components Using a controlled Irradiance Water Cooled Xenon-Arc Apparatus

UMTA-DC-06-0152-83-1, A Corrosion Control Manual for Rail Rapid Transit

PART T 19.00
QUALITY ASSURANCE

Table of Contents

19.01: GENERAL

A. This section describes the quality system requirements that shall be implemented by the Contractor and their subcontractors and suppliers. The quality assurance requirements for this technical specification shall be described in two parts; the Quality Management System requirements of the Contractor and their subcontractors and suppliers, and the requirements for the Project Quality Plan.

B. The Contractor's Quality Management System shall include the Quality System Manual and the Project Quality Plan. The Quality System Manual shall include a Quality Policy, a description of the responsibilities of key personnel affecting quality, and the corporate procedures and processes that affect the design, production and management and the requirements of Part 19.02.01. The Contractor's Quality Management System shall be in compliance with and certified, as meeting the requirements of the ANSI/ASQ 9001-2008 standard.

C. The Contractor's Quality System Manual and Certificate proving compliance to the ANSI/American Society for Quality (ASQ) 9001-2008 standard shall be submitted to the Authority for review and approval. [CDRL 19-01]

D. The Contractor shall designate a Quality Manager (QM) within the Contractor's organization with the overall responsibility of the effective implementation, management, planning and oversight of the Project Quality Plan. The QM shall have the authority and autonomy to fully exercise the requirements of the Project Quality Plan throughout the Contractor's organization, as well as the Contractor's Suppliers. The Quality Manager shall have a minimum of ten years experience with Quality Systems relative to Rail Car Manufacturing.

E. The Contractor's Project Quality Plan shall provide the details not covered in the Quality System Manual that describes the Contractor’s method to conform to the requirements of this Specification.

F. All the quality requirements set forth in this part of the specification shall be equally applied to the major subcontractor's performing the work or supplying material to the Contractor, including ANSI/ASQ ISO 9001-2008 certification. Subcontractors and suppliers that are not ANSI/ASQ ISO 9001-2008 certified shall be submitted by the Contractor to the Authority for review and approval. [CDRL 19-02]

G. The Contractor shall be appraised via SCAMPI A to Capability Maturity Model Integration (CMMI) Maturity Level 2 for Acquisition. Certification shall be achieved no later than 18 months from NTP. Proof of certification shall be provided to the Authority for review and Approval. [CDRL 19-03]

H. All Contractors and Sub-contractors who will develop non-COTS (Commercial Off The Shelf) and/or modified COTS software for components/systems required for this project shall be CMMI for Development (CMMI-DEV) Maturity Level 2, appraised via SCAMPI A. Certification shall be achieved no later than 18 months from NTP. Proof of certification shall be provided to the Authority for review and Approval. [CDRL 19-04]

I. The Authority reserves the right to perform quality inspections, audits and/or reviews at the Authority's discretion during the contract to ensure that the Contractor is meeting all of its Quality Management System requirements. The inspections, audits and/or reviews will be performed independent of and in addition to the Contractor's quality assurance (QA) functions. These monitoring functions will confirm that the Contractor has effectively implemented its quality system as well as confirming that Deliverables and Submittals under the Contract conform to the Specification including Authority approved drawings and documentation. Authority Inspectors and Auditors shall have free access to the Contractor's, subcontractor's and supplier's facilities during all normal business hours and when work is in progress.

J. The Quality Management System shall be consistent the Quality System Manual and sample Quality Plan outlines submitted as part of the Contractor's proposal.

K. The Contractor shall form a Failure Review Board (FRB) comprising representatives from the Contractor, Authority technical staff and representatives. The FRB shall have the level of responsibility and authority to assure that root causes and responsibility for failures are identified and corrective actions are effected in a timely manner for all non-nuisance failures in accordance with MIL-STD-785B. The FRB shall be implemented 60 days prior to Pilot Car Testing. Refer to T 02.03.06, Reliability Program Plan, for additional information.

19.02: QUALITY SYSTEM MANUAL

19.02.01. Quality System Manual Elements

A. The Contractor shall have a fully implemented and current Quality System Manual (QSM) and procedures that define its ANSI/ASQ ISO 9001-2008 Quality System.

B. The Manual shall include, as a minimum, the following policies, procedures and processes:

1. Quality Policy
2. Management Review
3. Document Control
4. Sub-contractor Management
5. Design Control
6. Manufacturing/Production Procedures
7. Calibration of Measuring Equipment and Tools
8. Control of Non-Conforming Product
9. Quality Records
10. Training

11. Quality Audits

12. Customer Satisfaction

13. Corrective and Preventive Action

14. Process Improvement

19.02.02. Certification of Personnel

A. Welders

1. Welders shall be qualified in accordance with the requirements of the AWS QC7-93, Standard for AWS Certified Welders.

2. Critical structural welds and repair welds to car-body structure and/or truck frames shall be inspected by welding inspectors certified in accordance with the AWS QC1:2007, Standard for AWS Certification of Welding Inspectors.

B. Auditors

1. The Contractor's quality auditors performing internal audits and/or audits of the Contractor's major subcontractors shall be certified by ASQ (ASQ-CQA), or approved equal.

C. Lead Inspector

1. The Contractor's Lead Quality Inspector(s) performing in-plant inspections shall be certified by ASQ (ASQ-CQI), or approved equal.

D. Quality Manager

1. The Contractor's Quality Manager, as described in 19.01.D above, shall be certified by ASQ (ASQ-CMQ/OE), or approved equal.

E. Certification Records

1. The Contractor shall maintain a database of employee certification and training records, including; employee name and identification number, certification description, certification body, original certification date, and certification expiration date.

19.02.03. Certificates of Compliance

A. With the Authority's approval, the Contractor may use certificates of compliance for certain materials and products in lieu of the specified sampling and testing procedures for demonstrating proof of compliance of materials. Each shall clearly identify the lot certified by the certificate and be signed by an authorized representative of the supplier or subcontractor, stating the material complies in all respects with the Contract requirements.

B. Accompanying the certificate of compliance shall be a certified copy of test results or a statement that such test results are on file with the supplier or subcontractor, and will be furnished to the Authority on request. Each certificate shall contain the information specified for samples, the name and address of the organization performing the tests, the date of the tests and the quantity of materials shipped.

19.02.04. Quality Assurance Audits

A. The Contractor shall perform audits of its Quality Management System, independent of the Project Specific audits described in the Project Quality Plan (PQP).

B. Audits of subcontractors and suppliers shall be made by the Contractor and may be witnessed by the Authority at the following times during the execution of the Contract work:

1. As a condition of the subcontract or purchase order, prior to the start of any work, and
2. Within a 30-calendar day period prior to formal acceptance by the Contractor of the first article inspection or services being supplied by the subcontractor or supplier.
3. When the supplier, or the supplier facility, manufacturing the product has changed.
4. When re-certification is warranted due to unacceptable performance, such as product non-conformance, schedule impact or cost overruns are encountered.

C. The Authority may conduct independent audits of the Contractor's, subcontractors and/or supplier's Quality Management System and PQP for its effectiveness at any time. The Contractor shall be responsible for overseeing corrective and preventive actions as a result of discovering problems or non-conformances during the audits.

19.03: PROJECT QUALITY PLAN

19.03.01. General Description

A. The Contractor shall establish and maintain a written Project Quality Plan (PQP) that shall be implemented for the full duration of the Contract. The PQP shall describe the detailed processes and procedures specifically required to meet the requirements of this Specification and Contract. If applicable, the PQP may reference policies and procedures included in the Contractor's QSM.

B. The PQP shall be submitted to the Authority, for review and approval, within 60 days of Notice To Proceed (NTP). [CDRL 19-05]

C. The Contractor shall conduct biannual reviews of the Contractor's PQP, with input and approval from the Authority. The first scheduled review shall be conducted one year from NTP.

19.03.02. Project Quality Plan Elements

A. The Contractor's PQP shall include, but not be limited to:

1. Project Description
2. Project Roles and Responsibilities
3. Project Specific Design Control Procedures
4. Project specific Production/Manufacturing Procedures
    a. Installation procedures, including but not limited to:
        (1) Component Mounting
        (2) Decal Application
        (3) General Fastening
        (4) Safety Critical Hardware and Fastening
        (5) Flooring
    b. Workmanship procedures, including but not limited to:
        (1) Wiring and Routing
        (2) Crimping
        (3) Labeling
        (4) Piping
        (5) Welding
        (6) Sealing
        (7) Leveling
        (8) Painting
    c. Torque Control procedures
    d. Calibration procedures
    e. Material Handling procedures, including but not limited to:
        (1) Carbody Lifting
        (2) Electro-Static Discharge procedures

(3) Material Shelf Life

(4) Vehicle Delivery Preparation

(5) Vehicle Unloading at Carhouse

5. Configuration Management

   a. Hardware

   b. Software

6. Engineering Change Control

7. Non-conforming Material Control Procedures

8. Procurement and Vendor Quality Procedures

9. Inspection Procedures, including but not limited to:

   a. First Article Inspections

   b. Incoming Inspection

   c. Hold Point Inspection

      (1) Carbody Structure

      (2) Carbody Water tightness

      (3) Interior Equipment Installation

      (4) Underfloor Equipment Installation

      (5) Piping and Wiring

      (6) Prior to Installation of Interior Wall Liners, Floor and Ceiling

      (7) Truck Installation

      (8) Final Car

   d. Source Inspection (if required)

   e. Pre-Shipment Inspection

   f. Receiving Inspection

   g. Field Modification Inspection

   h. Pre-Acceptance Inspection at Carhouse

10. Test Procedures, as further described in Part T 20, including but not limited to:

    a. Life-cycle Testing

    b. Material Testing

    c. Routine Testing

    d. System Testing

    e. Software Testing

    f. Integration Testing

    g. Pilot Car Testing

    h. Vehicle Testing

    i. Acceptance Testing

11. Warranty Management Procedures

19.04: MONTHLY QUALITY REPORT

A. The Contractor shall submit a Monthly Quality Report (MQR) that describes the status of key project elements described in the PQP as well as all other quality issues affecting the project. The Contractor shall submit a draft MQR to the Authority for review and approval within 60 days of NTP. [CDRL 19-06]

B. The MQR shall include, but not be limited to:

1. Description of the current status of the design and/or production status of the project

2. Status of PQP open issues

3. Status of First Article Inspection (FAI) open issues

4. Status of non-conforming material

5. Status of field modifications

6. Subcontractor and supplier audit results

7. Contractor's project audit schedule and results

    a. Internal - Contractor

    b. Vendors and Sub-contractors

8. Software quality assurance audit results

9. FRB major issues

C. The Contractor shall hold monthly Project Quality meetings with the Authority to discuss quality issues and review the MQR.

D. The Contractor shall, with the approval of the Authority, schedule Quarterly Quality Review Meetings to discuss current relevant production and quality related issues with the major sub-contractors from preliminary design to the warranty period.

19.05: FIRST ARTICLE INSPECTIONS

A. First Article Inspections (FAIs) shall be in accordance with the provisions in this section and section C5.19, First Article Inspections, Procedures and Test Specifications.

B. The planning, scheduling, tracking and completion of all FAIs shall be the Contractor's responsibility. No later than 60 days prior to the first scheduled FAI, the Contractor shall submit to the Authority for review and approval, an FAI plan, format and preliminary schedule. [CDRL 19-07]

C. At a minimum, FAI's shall be performed on all major components, subassemblies, systems, car structure at predetermined hold points and pilot cars. Subsystems shall include, but not be limited to:

1. Propulsion
2. Trucks and Major Truck Components
3. Auxiliary Inverters
4. Low Voltage DC Power
5. HVAC
6. Carshell
7. Couplers / Draft Gear
8. Wheel Sets
9. Air Brake Equipment and Controls
10. ATP/ASR Equipment
11. Door Systems
12. Seats
13. Vehicle Monitoring System
14. Network Integration

15. Communications Equipment including LED and LCD Signage

16. Lighting

D. The purpose of each FAI is to confirm that the supplier's first production submittal is representative of recognized manufacturing processes and that it complies with all established specifications and requirements prior to commencement of the production manufacturing schedule. Each FAI shall be conducted at the supplier's facility or designated facility where the specified manufacturing activities for production units are to occur. The Authority and/or designated representative shall participate in the evaluation of the First Article for their information and approval:

   1. To validate the product according to design, quality and manufacturing processes and capability of consistently producing an acceptable product.

   2. To review inspection and test plans and manufacturer capabilities, including all required documentation supporting the evaluation of the FAI.

   3. To establish baseline design configuration compliant with the contractual specification and meeting the Authority's requirements.

E. In addition, during each FAI, the Authority will:

   1. Review the status of the development of the Component/System/Vehicle manufacturer's draft maintenance and training manuals.

   2. Perform a review of the Component/System/Vehicle manufacturer's Calibration Program.

F. Documentation shall include all written and binding verification which validates the product against the contract specification, and shall include, but not be limited to:

   1. Test and inspection reports

   2. Lab analysis reports for applied materials

   3. Certificates of compliance

   4. Approved drawings and Bills of Material

   5. Draft Integrated Parts Catalog

   6. Draft Running Maintenance Manual

   7. Draft Heavy Maintenance Manual

   8. Draft Maintenance Planning Manual

   9. Conformance to Specification

   10. All pending Engineering Changes (ECN), approved deviations or waivers shall be

available and recorded as part of the actual configuration level.

G. Prerequisite requirements:

1. Supplier shall be pre-approved by the Contractor and the Authority prior to the scheduled FAI.

2. All product specifications including the Authority's conformed contract specifications, shall be known, understood and concurred with by the suppliers.

3. All suppliers shall have the Contractor's issued purchase order, clearly defining the complete contractual work scope, applicable specification and Quality Assurance/Quality Control (QA/QC) requirements.

4. All design specifications shall be approved by the Contractor.

5. Any and all prototypes, including associated test results, shall be approved by the Contractor.

6. Quality Plans shall be approved by the Contractor's Quality Assurance Department.

7. Qualification and routine factory tests shall first be approved by the Supplier and then validated by the Contractor for conformance to the Specifications.

8. Confirmation of the scheduled FAI shall be submitted to the Authority by the Contractor, 30 days prior to the FAI. Included shall be:

    a. Supplier contact information

    b. Location of FAI

    c. Date and Time of FAI

    d. Agenda

9. For each scheduled FAI the Contractor shall perform and submit to the Authority for review and approval, 14 days prior to the FAI, a completed pre-FAI report including:

    a. The location, date and time of the pre-FAI

    b. A completed routine test report

    c. All current configuration data including, drawing revision level, all applicable ECN's, Serial numbers of all test equipment, list of applicable material certifications, FAI participants, non-conformances.

    d. Detailed procedures and test specifications to which the system, subsystems or components shall be manufactured.

H. The Contractor shall maintain an FAI Open Items list that shall track the status of each planned and completed FAI. The Contractor shall submit a draft FAI Open Items List to the Authority for approval 30 days prior to the first scheduled FAI. [CDRL 19-08]

I. The system/component inspected during the FAI shall be retained by the manufacturer until the final vehicle is assembled as a representative "Golden Unit" for reference. The "Golden Unit" shall be brought up to date with the latest configuration of modifications and updates just prior to delivery.

19.06: CDRL ITEMS

CDRL 19-01, “Contractor's Quality Manual”, (Ref: T 19.01.C)

CDRL 19-02, “Subcontractors Not ANSI/ASQ ISO 9001 Certified”, (Ref: T 19.01.F)

CDRL 19-03, “CMMI-ACQ Level II for Software Acquisition Cert.”, (Ref: T 19.01.G)

CDRL 19-04, “CMMI-DEV Level II for Software Dev. Cert.”, (Ref: T 19.01.H)

CDRL 19-05, “Contractor's Project Quality Plan”, (Ref: T 19.03.01.B)

CDRL 19-06, “Monthly Quality Report”, (Ref: T 19.04.A)

CDRL 19-07, “FAI Plan – Format - Schedule”, (Ref: T 19.05.B)

CDRL 19-08, “FAI Open Items List”, (Ref: T 19.05.H)

19.07: REFERENCES

19.07.01. Standards Referenced

ANSI/AIAA Performance-Based Failure Review Board (FRB) Requirements (S_102_1_5_2009)

ANSI /ASQ ISO 9001-2008, Quality Management System: Requirements

ASQ, CQA, Certified Quality Auditor Requirements

AWS QC7-93, Standard for AWS Certified Welders

AWS QC1:2007, Standard for AWS Certified Welding Inspectors

CMMI-ACQ, Capability Maturity Model® Integration (CMMI) Model for Software Acquisition.

CMMI-DEV, Capability Maturity Model® Integration (CMMI) Model for Software Development.

19.07.02. Technical Specification Cross References

T 02, Vehicle Design Requirements
T 18, Materials & Workmanship
T 20, Testing & Validation

PART T 20.00

TESTING & VALIDATION

Table of Contents

20.01: GENERAL

A. T 20, Testing & Validation, is focused primarily on car and vehicle level tests. Qualification and production test requirements for subsystems are detailed in the technical sections of the specification.

B. The specification has been written with a focus on performance requirements and less emphasis on detailed design requirements. For this reason, qualification testing to prove compliance to the specification is quite extensive.

C. The tests listed here represent a 'floor' to testing requirements. Additional tests shall be performed by the Contractor as required to ensure complete compliance to the specification, as well as all applicable laws, regulations and standards.

D. Red Line and Orange Line systems and performance requirements that are largely identical may not require separate tests to be performed. During testing, the Contractor should qualify the system to the requirements of both Lines. The Authority reserves the right to require independent tests for both vehicle types.

E. The Authority may waive Qualification tests if identical or nearly identical equipment has been tested and proven to perform with the reliability numbers included in this document, and under similar operating and environmental conditions, for a time period of at least 5 years.

F. Component redesign after testing may invalidate any/all previously completed tests. The Contractor may request relief from retest from the Authority with valid justification. The Authority will consider requests on a case by case basis.

G. Vehicle Qualification tests are intended to take place on the first production vehicles (Pilot Cars). The Authority will consider alternative approaches that benefit the schedule and are of limited risk of failure and redesign.

H. Production Tests shall take place on all vehicles, including the Pilot Cars.

I. Environmental tests, track geometry tests and miscellaneous non-car test requirements are detailed in T 02.

20.02: TEST DOCUMENTATION

20.02.01. Test Plan

A. The Contractor shall prepare a Master Test Plan. The Test Plan shall include all tests required to prove complete compliance to the vehicle specification. [CDRL 20-01]

B. Test order shall be arranged, to the maximum extent possible, such that failures resulting in redesign do not nullify the results of successfully completed tests.

C. Subsystem performance requirements may be addressed in one or more comprehensive tests, as elected by the Contractor.

20.02.02. Test Procedures

A. All test procedures shall be authored by the Contractor or sub-supplier and follow the same format and structure, subject to review and comment by the Authority. Procedures shall include purpose, location of test, required tools, pre-requisite tests or activities, pass/fail criteria, name and signature of tester, and software and hardware revision level, where applicable. [CDRL 20-02]

B. No testing shall commence until the procedures have been completed and approved. To ensure sufficient review time, the contractor shall submit the procedures no less than 3 months before the planned test date.

20.02.03. Test Reports

A. Test reports shall be produced by the Contractor no later than 30 days after completion of the test and shall be submitted for review and approval by the Authority. [CDRL 20-03]

B. The test reports shall include all information necessary to demonstrate the successful completion of the tests, including, where applicable, chart recordings, electronic test data, and video or audio measurement data.

C. The contractor shall not schedule any sub-system First Article Inspections (FAIs) until all sub-system qualification tests and production tests have been completed and approved by the Authority. Exceptions to this requirement may be proposed for Authority consideration on a case by case basis.

D. In the case of the Pilot Cars, Authority accepted results of On-Site Tests (post-FAI) shall be required before final acceptance of the Pilot Cars is granted.

20.03: TEST PROTOCOL

20.03.01. Testing Location

A. Testing shall take place at locations approved by the Authority. The Authority reserves the right to require an independent lab to conduct any test or portion of a test.

B. Labs shall be certified to perform tests, if required by applicable agency or administration (e.g. AAR, ASTM, IEEE, etc.).

C. All equipment used in the performance of tests shall be calibrated by an independent test laboratory on an annual basis, or more often, if required by the specific test.

20.03.02. Test Notification

A. The Authority reserves the right to witness any test or portion of a test required on any vehicle delivered under this contract. The Contractor shall notify the Authority of any planned tests a minimum of 30 days prior to the test taking place.

20.04: TYPES OF TESTS

20.04.01. Component Qualification Tests

A. Components shall be Qualification tested before they are presented for review and approval at the FAI. FAI approval is required prior to sub-system installation on the Pilot Cars.

B. Component Qualification testing is documented in the technical sections (T 02 through T 25) and tabulated here for reference.

C. All testing shall be performed in fixtures that simulate component installation on the vehicle. Where possible, vehicle secondary structure shall be used to support components during qualification testing. Fixture design details shall be included in procedures.

D. Component Qualification Test Procedures and reports shall be submitted to the Authority for approval through the CDRL process.

20.04.02. Vehicle Qualification Tests on Pilot Cars

A. Qualification testing shall prove that the design is in compliance with the requirements of the specification. Qualification Test results of the Pilot Cars shall be equivalent to those that would be obtained on all production cars. Qualification testing is documented in T 20, with references identifying the specification section requiring the test.

B. Vehicles other than the Pilot Cars may be used to complete tests, such as carbody compression and HVAC Climate room, as deemed appropriate by the Authority.

C. Testing shall be performed on the completed vehicles with production components. Exceptions to this requirement may be considered on a case by case basis by the Authority.

20.04.03. On-Site Qualification Tests on Pilot Cars

A. On-Site Qualification Testing shall be done on the Authority's property by the Contractor. The Contractor is strongly urged to pre-test the Pilot cars before shipment, to ensure field modifications and re-tests are avoided. Authorization to ship the Pilot cars does not relieve the Contractor from successfully completing these tests. Conditional acceptance of the Pilot cars and initiation of the milestone payment shall require all testing and FAI issues to be closed.

B. Tests shall take place on a 4 car train-set (2 Married Pairs), unless test specifics require an alternate configuration.

20.04.04. Component Production Tests

A. Components shall be Production tested at the sub-suppliers factory before shipment to the Contractor.

B. Test reports shall be shipped with each component. Copies of the test reports shall be included in each Car History Book.

C. Testing shall be performed in fixtures that simulate component installation on the vehicle. Where possible, vehicle secondary structure shall be used to support components during production testing. Fixture design details shall be included in procedures.

D. Component Production testing is detailed in the sections T02 through T25.

20.04.05. Vehicle Production Tests

A. Vehicle Production Tests shall be completed before the Contractor requests permission to ship each car.

B. Test reports shall be shipped with each vehicle. Copies of the test report shall be included in the Car History Book.

20.04.06. On-Site Commissioning Tests

A. Vehicles arriving on Authority property shall be commissioning tested to ensure they are ready to run in revenue service.

B. Testing shall include all qualification tests whose results may deviate from the Pilot Cars, tests required to ensure the vehicle is safe and tests required to set up the vehicle for proper operation.

C. Testing shall also include all production tests required to verify complete functionality of all equipment. Contractor requests to abridge this testing shall be proposed and justified to the Authority for consideration.

D. Tests shall take place on a 4 car train-set (2 Married Pairs), unless test specifics require an alternate configuration.

20.05: QUALIFICATION TESTS

20.05.01. General

A. Requirements for qualification testing for individual parts and sub-systems are defined in the individual sections of this specification.

20.06: CARSHELL (AND TRUCK) QUALIFICATION TESTS ON PILOT CARS

20.06.01. Clearance Tests

A. The vehicle shall be arranged to simulate the combined dimensional conditions of fully worn wheels, over-inflated or deflated springs, maximum passenger load and worst case track perturbations (as measured by the Contractor). Measurements shall be taken to ensure: See T 3.04.08 and T 2.01.05

1. For carbody mounted equipment less than 5 (127 mm) inches above top of third rail, the lateral clearance between carbody mounted equipment and the third rail shall not be less than 35 inches (890 mm).

2. For carbody mounted equipment greater than 35 inches from third rail, the vertical clearance between carbody mounted equipment and top of rail shall not be less than 4.75 inches (121 mm).

3. The vertical clearance between truck mounted equipment and the third rail shall be a minimum of 3.0 inches (76.2 mm).

4. The lateral clearance between truck mounted equipment and the third rail shall be a minimum of 3.5 inches (88.9 mm).

5. The vertical clearance between truck mounted equipment and top of rail shall be a minimum of 2.75 inches (70 mm).

B. Wayside clearances calculated under CDRL 03-19 for the clearance envelope shall be verified: See T 3.04.08

1. Simulated conditions above with worst case carbody roll shall be measured.

2. Maximum vehicle height (new wheels, maximum suspension travel upwards, and worst case carbody roll) shall be measured.

C. Both trucks shall be rotated to maximum angles to ensure sufficient slack has been provided on all truck to carbody connections. Tests shall be performed at both the minimum and maximum vehicle heights.

1. Clearance between carbody mounted equipment and the truck shall not be less than 1.0 inch (25.4 mm).

20.06.02. Weight Imbalance Tests

A. Load cells shall be used at each wheel to determine the wheel load of the 8 wheels of the completed car.

1. Each truck under the Cab Car shall support 49% to 51% of the vehicle weight. See T 2.01.09

2. Each Non-Cab Car truck shall support 49.5% to 50.5% of the vehicle weight. (See T 2.01.09

3. Wheel loads shall be 23%-27% of the total weight on the 4 wheels of each truck. See T 11.10.02

4. The maximum lateral imbalance shall be equal to or less than 25,000 in-lbs (2,825 N-m). See T 2.01.09

20.06.03. Wheel Load Equalization Tests

A. Load cells under each wheel of the car shall measure the static wheel load on each wheel (on level track).

1. Each wheel shall be raised and then lowered by 1 inch (25.4 mm). No wheel load shall increase or decrease more than 17 percent. See T 11.10.02

2. Each wheel shall be raised and then lowered by the maximum reserve deflection shown in the truck assembly drawing. No wheel load shall increase or decrease more than 95 percent. See T 11.10.02

3. The wheels on one side of the car shall all be raised to the maximum superelevation shown in T 2. Minimum wheel load shall be no less than 60% of the normal static wheel load measured on level track. See T 11.10.01

20.06.04. Secondary Suspension Tests

A. One air spring shall be exhausted to ensure the mating spring vents. See T 11.06.02

20.07: COUPLER QUALIFICATION TESTING ON PILOT CARS

20.07.01. Front End Coupler Coupling and Uncoupling Test

A. Two Married Pairs shall be used to confirm that coupling and uncoupling operations are easily performed with all scenarios:

1. Verifications shall be made by coupling/uncoupling from a Cab Car and from the hostler panel of a Non-Cab Car.

2. Coupling with and without the inching controls shall be demonstrated.

20.07.02. Coupler Manual Force Requirements

A. The force required at the manual lever for manual uncoupling shall be measured and shall not exceed 70 pounds (311 N). See T 4.03.06

B. After negating the centering device, the force required for manual positioning shall be measured and shall not exceed 85 pounds (378 N) at the coupler head. See T 4.03.07

20.07.03. Centering Ability Test

A. The centering device shall be tested to verify proper operation through cab controls, hostler panel controls and manual controls. Force resistance and coupler freedom of travel when disengaged shall be measured.

B. When Married Pairs are uncoupled, the centering device shall maintain the coupler within ±1.0 inches (±25.4 mm) of vehicle centerline. See T 4.02.02

20.07.04. Coupler Gathering and Freedom of Movement

A. Couplers shall fully couple with a vertical offset of ± 3 3/4 inches (95 mm), a lateral offset of ± 3 3/4 inches (95 mm) and up to 12.0 degrees of rotational mismatch. See T 4.03.05

B. Couplers shall withstand horizontal pivot angles of ± 29.5 degrees and a 110 foot (33.5 m) radius horizontal curve without damage or binding.

C. Couplers shall withstand vertical pivot angles of ± 10 degrees without damage or binding.

D. Couplers shall withstand ± 6 degrees rotation about the coupler axis without damage or binding.

20.07.05. Coupler and Draft Gear Clearance Test

A. During the coupler gathering and freedom of Movement Tests listed above, the coupler heads, hoses and electrical cables shall be verified to maintain a minimum of 1.5 inches clearance between the coupler components and the vehicle.

1. Sufficient slack shall be present in all clamps, cables, hoses and wiring. Minimum bend radii of conduit, hoses, cables and wiring shall not be exceeded.

20.07.06. Automatic Coupler Step Strength Test

A. The coupler step shall be loaded to 400 lb (181 kg) applied to a 6 sq-in area (39 sq-cm) without resulting in any damage or permanent deformation.

20.07.07. Cab Controls Test

A. Electrical isolation, circuit closing and circuit looping shall be demonstrated by the contractor. The following requirements shall also be met:

1. Network connections shall not be switched by a drum switch. See T 4.02.11

2. Electrical heads shall be retracted between coupled cars to demonstrate electrical isolation. Bell, Battery Negative and Train Ethernet Network trainline connections shall always be made, regardless of electrical head position.

20.07.08. Pneumatic Coupling Tests

A. Controls that allow pneumatic isolation in each cab and hostler panel shall be verified to function properly. See T 4.02.09

B. A Married Pair shall be coupled to a Married Pair with a faulty air compressor. Sufficient air shall be provided through the coupler trainlines to charge the disabled pair and provide sufficient air for normal operation of the train-set by the single air compressor. See T 4.02.07

C. An unintentional uncoupling shall be verified to vent air from the emergency brake pipe of both vehicles. See T 4.02.07

20.07.09. Coupler & Coupler Anchor Strength Test

A. The following tests may be included in the carbody compression test at the discretion of the Contractor.

1. A 75,000 pound (334,000 N) vertical load shall be applied, in both directions, to the coupler at the coupler face. Components and car structure shall withstand the load without yielding. See T 4.03.02

2. A 150,000 pound (734,000 N) horizontal load shall be applied to the coupler face, in both tension and compression. The coupler and car structure shall withstand the loads without yielding.

3. See T 03, Carbody, for carshell strength requirements and coupler/coupler anchor test setup. See T 3.05.03.

20.08: OPERATOR'S CAB QUALIFICATION TESTING ON PILOT CARS

20.08.01. Cab Wall Testing

A. A load of 200 lbs (890 N) shall be applied to a 6 in x 6 in (152 mm x 152 mm) surface area, anywhere on the wall, and result in no permanent deformation. See T 5.02.01

B. A force of 500 lbs (2,224 N) shall be applied to a 24 in x 24 in (610 mm x 610 mm) surface area and result in no permanent deformation. See T 5.02.01

20.08.02. Cab Door Tests

A. The lock shall be verified to automatically release and remain unlocked when the Passenger Emergency Stop is actuated. See T 5.02.02

B. The cab doors shall be pushed open several times with various force levels. The hold open devices shall latch the cab door each time and prevent damage from occurring to the door panel or cab interiors.

C. A load of 200 lbs (890 N) shall be applied to a 6 in x 6 in (152 mm x 152 mm) surface area and result in no permanent deformation. See T 5.02.02

D. A force of 500 lbs (2,224 N) shall be applied to a 24 in x 24 in (610 mm x 610 mm) surface area and result in no permanent deformation. See T 5.02.02

20.08.03. Windshield Tests

A. The windshield over-temperature protection and manual reset shall be validated. See T 5.02.06

   1. The reset device shall be accessible by the Operator from a seated position.

   2. Manual reset requirement shall be displayed on Operator's console.

B. Over-temperature shall not result from continuous operation at any ambient temperature below 60°F (16°C).

20.08.04. Wiper and Washer System Tests

A. The wiper arm shall be verified to remain vertical throughout its sweep. See T 5.02.07

B. The parked position of the wiper blade shall be the extreme right or left side of the windshield.

C. The wiper blade swept surface shall be at least 75% of the windshield surface.

D. The washer spray nozzle(s) shall cover the blade swept area with cleaning solution. See T 5.02.08

20.08.05. Horn Testing

A. The horn shall have a minimum sound pressure of 95 dBA at a distance of 100 feet (30.5 m) in front of the train. See T 5.02.09

20.08.06. Instructor's Seat

A. A load of 400 pounds (181 kg) shall be applied to the seat portion of the instructor's seat. The load shall not damage the seat, its mounting, or cause any permanent deformation. See T 5.04.03

20.08.07. Convenience Outlet

A. A load just above the 20 amp limit of the outlet shall be applied to ensure the circuit breaker trips the outlet. See T 5.04.05

B. The GFI device shall be tripped and reset.

20.08.08. Sun Visor Design Verification

A. The visor shall be verified to be fully adjustable over the range of the windshield and side window.

B. If translucent, the visor shall be tested to ensure that the colors of objects are not distorted when viewed through it. See T 5.04.06

C. The visor shall be verified to provide sufficient eye protection for the Operator.

20.08.09. Emergency Evacuation Ladders

A. The design of the quick release mechanism shall firmly secure the ladder in place yet allow the Operator to easily release and remove it. See T 5.10.01

B. The ladder shall be positioned into the anticlimber holes and verified to sit securely on the track bed.

C. The ladder shall then receive a 450 lb (205kg) load applied on all steps, one at a time. No damage shall occur.

20.08.10. Emergency Egress Chairs

A. The design of the evacuation chair's quick release mechanism shall firmly support it in place yet allow the Operator to easily release and remove the chair. See T 5.10.02

B. The chair shall be verified to slide down the emergency evacuation ladder in a stable, balanced manner.

C. The chair shall be of sufficient strength to support a 450 lb (205 kg) load.

20.08.11. Fire Extinguisher accessibility Testing

A. The two fire extinguishers located in the Cab shall be firmly supported in place, yet easily removable by the Operator.

B. The frangible cover over the Non-Cab Car fire extinguishers shall be robust, yet easily broken when kicked. The cover shall break cleanly away to allow unimpeded access to the quick release clamps of both extinguishers. See T 5.10.05

20.09: SIDE DOOR QUALIFICATION TESTING ON PILOT CARS

20.09.01. Door Operation Qualification Tests

A. Door opening and closing times shall be adjusted via the PTU, and set to times of 2.5 seconds ± 10% to open, and 3.0 seconds ± 10% to close (unless a modified open or closing time was elected during the design phase. See T 6.06

1. The Contractor shall demonstrate that the door operator adjusts motor amperage to maintain opening and closing times as a result of increased resistance (such as, as a result of dirt accumulation in the track).

B. The door controller shall coordinate the timing of door leaves to ensure that both reach the fully closed and open positions at the same time (±250 ms). See T 6.02.06

1. The door opening clear width shall be at least 64 inches (1626 mm) with two door leaves open.

C. All door panel cutout locks shall be tested to ensure they securely fix the door in place and close the switches required to make the door summary loop.

D. Operation of a single leaf within a doorway shall be Qualification tested on the first Married Pair to prove compliance with the specification.

1. The door opening clear width shall be at least 32 inches (813 mm) with a single leaf open. See T 6.02.02

2. Obstruct one door panel and verify that the adjacent panel closes and locks. See T 6.01

3. Verify that one door panel may be locked out and the adjacent panel continues to operate normally.

a. Bridgeplate shall not deploy if a single panel opens. See T 6.02.10

20.09.02. Car and Side Door Indicator Tests

A. Local interior and exterior door indicators shall be verified to function properly:

1. Door open indicator lights shall be energized when the doors commence opening.

2. Indicator lights and Door open audible chime shall function according to agreements during design review.

3. Indicator lights and Door close audible chime shall function according to agreements during design review

4. A door fault shall be simulated to demonstrate that the door open indicators adjacent to the doorway flash until the fault is cleared or the door is closed and locked out. See T 06.02.07

B. The Cab Indicator Lights shall be checked for correct functionality:

1. The door summary indicator light on the cab console shall energize when all cars have a closed door summary loop. See T 6.04.01

2. The Door Interlock Bypass indicator light on the cab console shall be lit whenever the Interlock Bypass switch is thrown. This shall only function in the controlling cab. See T 6.04.01

3. The No-Motion Bypass indicator light on the cab console shall energize when the No-motion switch is in the Bypass mode. See T 6.04.01

20.09.03. Crew Switch Qualification Tests

A. Crew Switches shall be tested to ensure that.

1. The crew switch shall open the door within 2 seconds after rotation of lock.

   a. The doors will operate for a minimum of 30 minutes after loss of LVPS. See T 6.02.04

2. The crew switch shall be interlocked with the No-Motion circuit to preclude opening the door with the car in motion. See T 6.03.04

20.09.04. Manual Door Release Qualification Tests

A. The manual door releases shall be measured and tested to prove specification compliance:

1. The force required to activate the interior manual release shall not exceed 20 lbf (89 N). See T 6.05.01

2. The force required to pull the exterior T handle manual release shall not exceed 50 lbf (222 N). See T 6.05.01

3. The force required to slide the door panel into the door pocket shall not exceed 35 lbf (156 N). See T 6.05.01

4. Manually closing the doors shall automatically reset the emergency release device. See T 6.05.01

B. Activation of any manual door release shall interrupt the door summary circuit, disabling propulsion and applying full service brakes.

1. Activation of any manual release shall unlock and partially open the local door panel and enable the door panel to be manually opened, regardless of vehicle speed. Release of a door in a moving car shall initiate full service braking and disable propulsion. See T 6.05.01

2. The VMS shall display the unlocked door and the door open indicator light shall be energized. See T 6.05.01

20.09.05. Door Adjustability Qualification tests

A. The Contractor shall demonstrate door panel adjustment in both horizontal and vertical directions with an eccentric nut, or similar device. See T 6.02.09

20.09.06. Door Cutout Switch Qualification Tests

A. The Door Interlock Bypass switch shall allow propulsion to be taken on a train-set when all doors are not closed and/or locked.

1. The Door Interlock Bypass Switch shall be tested to ensure that it only functions when thrown in the controlling cab.

B. The Door Summary Relay shall prevent the train from releasing brakes or taking power until:

1. All doors/bridgeplates are closed and locked and the Enable function is canceled (by a Close command). See T 06.03.02

C. Both of the sealed Door Isolation switches shall be cut out (one at a time). The doors on the car that is isolated shall be prevented from opening. See T 6.03.02

D. The No-Motion Relay functionality shall be tested per the following:

1. The side doors shall not open or become enabled until the no-motion relay picks up. See T 6.03.02

2. Door open and enable requests above the no-motion point shall be cancelled. The door open or enable request must be received below the no-motion point to be acknowledged. See T 6.03.02

3. All open doors (and deployed bridgeplates) on the car shall immediately be powered closed if the car's No-Motion Relay drops out. See T 6.03.02 Obstruction detection shall be disabled under this condition.

E. The Door Open Relay shall be tested to ensure that: See T 6.03.02

1. It requires the No-Motion relay to energize and both the Door Unlock and the Door Open trainlines to be active for a particular side before microprocessors are allowed to open the doors.

2. Trainlined Close commands shall cause the door open relay to drop out, which will force all microprocessors to close and lock the doors, regardless of the most recent microprocessor output signal.

F. Bridgeplates shall be tested to ensure that:

1. Manual deployment and retraction shall be easily accomplished without the use of special tools See T 6.02.10

20.09.07. Obstruction Detection Qualification Testing

A. Obstruction detection testing shall be performed throughout the range of heights - 3 inches (76.2 mm) below top of door edge to 1 inch (25.4 mm) above bottom of door panel. See T 6.06.05

1. A flat bar, 1/4 inch (6.35 mm) wide and 3 inches (76.2 mm) high, held between the panels, perpendicular to the door.

2. A 3/8 inch (9.5 mm) diameter rod, held between and perpendicular to the door.

3. The door panels shall permit a thin flexible object not detected by the detection system to be pulled free from the leading edges of doors that are fully closed and locked.

B. When an obstruction is detected, the obstructed panel or panels shall fully open, pause for 1/2 a second (or revised time selected by Authority) and then commence closing. The door panels shall recycle in this manner until the obstruction is cleared and the panel successfully closes. See T 6.06.05

C. Static forces generated by the door operator shall be measured. Forces shall not exceed 30 lbf (133 N), measured at the leading edge of the door leaf at any position between 2 inches (51 mm) from the fully open position to 2 inches (51 mm) from the fully closed position. See T 6.06.03

D. A force of 60 lbf (266 N) shall be applied perpendicular to the door panel, at a vertical level of half the doorway height, and shall not prevent the door from opening or closing. See T 6.06.03

20.10: HVAC SYSTEM QUALIFICATION TESTING ON PILOT CARS

20.10.01. General

A. Tests 20.10.01 through 20.10.25 below shall be performed at an independent Climate Room, certified for rail car qualification testing. Alternative test locations may be proposed by the Contractor, with appropriate justification, certification and a proven history of testing, for Authority consideration.

B. The climate room shall utilize only calibrated equipment. All devices shall be verified to be accurate to the satisfaction of the Authority.

C. A minimum of 75 thermocouples shall be used to determine the average interior temperature of the vehicle. Thermocouples placement shall be proposed by the Contractor for acceptance by the Authority.

20.10.02. Fresh and Return Air Volume Test

A. Fresh, return and supply air flows shall be measured. The fresh air volume drawn into the vehicle (with all filters installed and all car doors and windows closed) shall be no less than the requirement in the approved load calculations. Return air volume shall be no less than the volume achieved in the unit qualification test to achieve capacity.

B. Each unit shall handle 50% of the fresh and return air volume, ±5%.

C. A measurable positive pressure shall be achieved inside the vehicle while the measurements are taken.

D. Balancing devices, if required, shall be designed, installed and approved by the Authority before proceeding to the next test.

20.10.03. Air Balance

A. Diffusers shall be balanced down the length of the car to ensure that the volume from each 3 foot (0.9 m) length of diffuser is within 10% of the nominal volume in Cubic Feet per Minute (CFM).

B. Total cab air volume with diffusers fully open and cab door closed shall be verified to be in a minimum of 400 CFM (11.3 cubic-m per minute).

C. Approved passenger area diffuser settings shall be documented and incorporated into all production vehicles as fixed, non-adjustable settings.

20.10.04. Velocities

A. The maximum air velocity shall be less than 1200 Feet Per Minute (FPM) (6.1 m/s).

B. Fresh and return air filter sizes shall be cross checked against air volume to ensure velocity is 450 FPM (2.3 m/s) or lower.

C. Return air grille air velocity shall be less than 350 FPM (1.8 m/s).

D. Fresh air inlet velocity shall be less than 400 FPM (2.0m/s).

E. Diffuser outlet velocity shall not exceed 175 FPM (.9 m/s) 6 inches (152 mm) from the outlet.

F. Air velocity anywhere in the car, 48 inches (1219 mm) above the floor shall not exceed 50 FPM (0.25 m/s).

20.10.05. HVAC Train Control Tests

A. Verify that the HVAC units operate when a Master Controller in the train-set is energized (and 15 minutes after shutdown).

B. The trainlined HVAC Shutdown signal shall immediately de-energize all HVAC units when commanded from the Cab Console.

20.10.06. Air Damper Tests

A. Smoke shall be introduced to the fresh/return air mixing plenum and the supply air duct, one at a time.

B. All dampers on the car shall close within 5 seconds of an activation of a smoke detector. Dampers may be re-opened only after the smoke is no longer detected and a manual reset signal is sent from the Operator's cab. See T 7.02.078

C. An alarm and a VMS warning shall be verified in the cab.

D. Dampers shall be verified to close (if applicable) when the return air temperature is below 50°F (10°C) or above 80°F (29°C). See T 7.02.07

20.10.07. HVAC Heater Safety Tests

A. The overhead heater shall be operated while the return air duct is slowly blocked. The over-temperature thermostat shall cycle power to the heaters, on and off, without tripping the back-up device.

B. Blower shall be disconnected and the heater interlock and motor current device jumpered, so that heaters remain on without air flow. The over-temperature thermostat shall cycle the heaters without tripping the back-up device.

C. Test B shall be repeated with the over-temperature thermostat jumpered. The fuse link or shunt trip device shall open the high voltage heater circuit before smoke or odor emanates from the unit.

D. If the unit is fitted with open coil-type heaters, the contractor shall demonstrate that the access covers cannot be lifted without automatic power removal from the heaters.

1. Over-temperature protection devices shall not trip during normal shutdown of the system, or after a loss of 600V power.

E. A floor heat ground fault shall be introduced into the floor heat circuit to ensure that the heaters are disabled / shunt tripped. See T 7.03.03

20.10.08. Cab Heater Safety Devices

A. The cab heater shall be run with the dial set to the hottest setpoint and at low and then high fan speed. Operation time shall be a minimum of 30 minutes at each fan setting. With the cab ambient temperature no colder than 65°F (18°C), surfaces of the cab heater shall be probed to ensure no surface exposed to the Operator is above 125°F (51.7°C).

B. The cab heater shall be verified to cycle on the over-temperature thermostat without tripping the manual reset during the following tests:

1. The inlet airflow will be blocked.

2. The blower motor will be disabled.

C. The over-temp thermostat shall be jumpered and the heater shall be energized to cause the manually resettable shunt trip breaker to open power to the heaters. Manual reset switch will be reset and the unit will return to normal operation.

D. During these tests, no smoke or odor shall emanate from the heater unit.

20.10.09. Temperature Control Matrix Verification Test

A. Return air and ambient air shall be varied throughout the range of conditions experienced in the authority's operating environment. Verification of the temperature control matrix through all modes of operation and all switching points shall be performed.

B. System modulation and current draw from each component shall be evaluated to determine performance of the variable voltage inverter control. Set points will be tested to ensure that "short cycling" does not occur and that the inverters allow dehumidification to be the dominant mode in mild conditions.

C. The microprocessor shall be accessed through the PTU to verify that the setpoint can be increased and decreased 5°F (2.8°C) in 1 degree increments for all switching points. See T 7.03.01

20.10.10. HVAC Communication & Failure Compensation Demonstration

A. A failure of the communication link between units shall be simulated to ensure that the units defer to their respective temperature sensors and operate accordingly. See T 7.03.01

B. After a simulated failure of one unit is created, the second unit shall detect the failure and change modes or operational logic to compensate for the failure.

20.10.11. Low Ambient Temperature Operation

A. Ambient temperature shall be lowered to 45°F (7.2°C). Return air temperature shall be slowly increased by adjusting simulated passenger loading until the unit is running in a partial cooling mode continuously. After one hour of operation, no evidence of coil freeze up shall be visible and adequate oil return to the compressor shall be verified.

20.10.12. Pull Down Test

A. The Climate room shall be set to 91°F dry bulb / 73°F wet bulb (32.8°C dry bulb / 22.8°C wet bulb) and the vehicle shall be left to soak overnight.

B. Testing shall commence the next morning (minimum 4 hour soak). All interior loads shall be energized to simulate design conditions.

C. The vehicle shall be energized and the time required to reach the partial cool switch point shall be determined. Damper position shall be monitored during test.

D. The test is passed if the average of the 2 temperature sensors is 74°F (23.3°C) or less after 30 minutes of operation.

20.10.13. Steady State at Design Conditions - Air Conditioning

A. After completion of the pull down test, conditions will be allowed to reach steady state. Interior average temperature shall be 72-74°F (22.2-23.3°C)

B. The relative humidity in the interior of the car shall be maintained between 30-60%. Condensate shall not form on any surface of the HVAC unit or vehicle.

C. Temperature stratification will be limited to the following, in both heating and cooling modes:

1. Maximum temperature difference throughout all horizontal planes through the passenger area shall be 4°F.

2. Maximum temperature difference within all vertical planes in the passenger area shall be 4°F.

3. Cab average temperature shall be ±2°F of the average passenger area temperature after vehicle stabilization. Stratification requirements of passenger area apply to the cab area.

20.10.14. Door Cycling - Air Conditioning

A. With the steady state conditions listed above (91°F dry bulb / 73°F wet bulb (32.8°C dry bulb / 22.8°C wet bulb)), all doors on one side of the car shall be opened for 30 seconds and then closed for 90 seconds. This process shall be repeated for 30 minutes.

1. The return air temperature shall be within 3°F (1.6°C) of setpoint, 90 seconds after doors close, throughout the full 30 minute test.

2. The interior average shall be within 3°F (1.6°C) 4 minutes after the final 30 second door opening cycle.

20.10.15. Condensate Carry-Over

A. The climate chamber shall be raised to 80°FDB (26.7°CDB), 75°FWB (23.9°CWB). All doors shall be opened and AW2 passenger loading shall be energized. The system shall be run in normal operation for a period of 1 hour.

1. No condensate shall blow off the coil.

2. All condensate inside the unit shall be collected and removed via the drain pan.

B. Condensate shall not form on any surface of the HVAC unit or vehicle.

20.10.16. Maximum Operating Conditions

A. The ambient and condenser inlet air temperature shall be raised to 110 °F (43°C) and simulated AW2 passenger load applied to the interior. Air conditioning shall still be available, at a reduced performance mode, if necessary.

B. Modulation control and capacity control shall be demonstrated.

C. A portion of the condenser coil surface area shall be blocked to increase the discharge pressure. The system shall shutdown in a safe manner, before excessive pressures are reached. The system shall automatically restart once system pressures begin to fall.

20.10.17. High Ambient Temperature Operation

A. Ambient and condenser conditions shall be slowly raised until the unit shuts down. Verification of an orderly, safe termination of performance shall be demonstrated.

20.10.18. UA (Carbody Conductivity) Test

A. The climate room shall be lowered to 8°F (-13.3°C) and layover heat mode shall be energized and the layover thermostat jumpered. Once steady state is attained, the calculated UA value shall be 800 BTU/hr-°F or lower.

B. Dampers shall be closed during the test. See T 7.02.07

C. Upon completion of the test, the layover thermostat jumper shall be removed to verify the car interior average is maintained between 40°F (4.4°C) and 50°F (10°C). See T 7.02.09

20.10.19. Pull Up Test

A. The Climate room shall be set to 8°F (-13.3°C) and the vehicle shall be left to soak overnight.

B. Testing shall commence the next morning (minimum 4 hour soak). All interior loads shall be de-energized to simulate winter design conditions.

C. The vehicle shall be energized and the time required to reach the partial heating switch point shall be determined. Damper position shall be monitored during test.

D. The test is passed if the average of the return air sensors is at least 66°F (18.9°C) after 30 minutes.

E. Duct sensors shall be monitored during the test (sensors shall limit the supply air temperature, unless the return air temperature is below 55°F (12.8°C)). See T 7.02.04

20.10.20. Steady State Heating at Design Conditions - Heating

A. After completion of the pull up, conditions will be allowed to reach steady state. Interior average temperature shall be 66-68°F (18.9-20.0°C)

B. The relative humidity in the interior of the car shall be maintained between 30-60%.

C. Duct sensors shall be verified to limit the supply air temperature to a maximum of 15°F (8.3°C) above return air temperature. See T 7.02.04

D. Temperature stratification will be limited to the following, in both heating and cooling modes:

1. Maximum temperature difference throughout all horizontal planes through the passenger area shall be 4°F.

2. Maximum temperature difference within all vertical planes in the passenger area shall be 4°F.

3. Cab average temperature will be ±2°F of the average passenger area temperature after vehicle stabilization. Stratification requirements of passenger area apply to the cab area.

E. Humidity control shall be available in ambient temperatures as low as 45°F (7.2°C). See T 7.07.01

20.10.21. Door Cycling - Heating

A. With the steady state conditions listed above (8°F (-13.3°C)), all doors on one side of the car shall be opened for 30 seconds and then closed for 90 seconds. This process shall be repeated for 30 minutes.

1. The return air temperature shall be within 3°F (1.6°C) of setpoint, 90 seconds after doors close, throughout the full 30 minute test.

2. The interior average shall be within 3°F (1.6°C), 4 minutes after the final 30 second door opening cycle.

20.10.22. Heater Guard Surface Temperature Test

A. After conclusion of the Door Cycling Test, the heater guard temperatures shall be measured to determine the maximum surface temperature.

1. The maximum guard temperature (or other component exposed to passengers) shall be located and recorded. Surface temperature shall not exceed 125°F (51.7°C). See T 14.05.04

20.10.23. Heated Windshield Tests

A. The climate room shall be left at 8°F (-13.3°C) and interior heat loads de-energized. The windshields shall be sprayed to create a 1 mm layer of ice. The side windows shall be fogged over until condensate begins to run down the glass. See T 5.02.05

1. The cab heaters shall be set to the side windows and energized in high fan, max heat. The windshield heaters shall be simultaneously energized.

2. The windshield heater shall clear a minimum of 75% of the windshield surface area in 15 minutes or less. Un-cleared areas shall be limited to a 2 inch (51 mm) band around the perimeter of the glass.

3. The Cab heater shall effectively clear the fog from 75% of the side window in 15 minutes or less.

20.10.24. Cab Heat Test

1. All interior heat loads shall be de-energized and the overhead air diffusers closed.

2. Allow steady state temperatures to be reached. The cab heaters shall have the capacity to maintain the cab interior average temperature at 70°F (21.1°C).

20.10.25. Snow Ingestion Testing

A. Fine, light snow shall be introduced to vehicle intakes. The following shall be verified after 10 minutes of snow:

1. The air inlet openings of the HVAC units, LVPS, API and Propulsion inverters (if air cooling is used on these components) shall not become clogged or ingest moisture.

2. HVAC unit fresh air filters shall not be exposed to moisture.

3. Side door threshold heaters shall be tested to ensure they clear 1/4 inch (6 mm) of compacted snow from the threshold and entire door track within 20 minutes. See T 14.03.04

20.11: LIGHTING QUALIFICATION TESTS ON PILOT CARS

20.11.01. Lighting Requirement Validation Tests

A. Verify that all LED driver boards conform to the following requirements: See T 8.05.01

1. Boards illuminate in less than one second.

2. Do not draw power when the LED lamps are off.

3. Control of LED currents shall not cause any noticeable light flickering. See T 8.05.01

20.11.02. Passenger Light Intensity requirements

A. Verify (with an approved light meter) the following locations and light intensities: See T 8.05.03

1. 33 inches (838 mm) above the floor on a 45º plane centered on the front edge of any seat - 35 foot-candles (377 lux).

2. 55 inches (1400 mm) above the floor on a 45º plane for passengers standing anywhere in the aisles - 35 foot-candles (377 lux).

3. At the floor in the passenger aisles and passenger side door vestibule areas between the windscreens - 20 foot-candles (215 lux).

4. End Door threshold with doors open and passengers standing in the door vestibule - 2 foot candles.

5. On the Operator's console (cab lighting) - 25 foot-candles (269 lux).

B. Emergency lighting - Exceed APTA RT-S-VIM-020-10, Standard for Emergency Lighting System Design for Rail Transit Vehicles.

20.11.03. Headlight Intensity Requirements

A. The high beam lights shall allow sufficient light to view a 50th percentile man 800 feet (244 m) away.

B. The high beam lights shall allow sufficient light to view a 50th percentile man wearing a reflective vest 1200 feet (366 m) away.

C. The low beam light shall strike the tracks at approximately 150 feet (45.7 m) in front of the car. This setting shall be verified by the Authority during On-Site Qualification testing See T 20.20.22.

20.11.04. Miscellaneous Lighting Intensity Requirements

A. Tail lights and Marker lights shall provide visibility in accordance with 49 CFR 221.14.

B. All exterior indicators shall be clearly visible from twelve cars away for those viewed in the longitudinal direction and minimum of 50 feet (15 m) for those viewed in the transverse direction. Tests shall be conducted in bright sunlight.

C. Loop step lights and end door light intensity shall be per the results of the mock-up and as agreed by the Authority.

20.11.05. Safety Feature Verification:

A. Lighting equipment shall be tested to ensure: See T 8.09.01

1. Over-temperature protection automatically resets the device when temperature level allows.

2. All powered terminals are covered when the lamp is removed.

20.12: LVPS AND INVERTER QUALIFICATION TEST ON PILOT CARS

20.12.01. Shop Power Plug Test

A. The Married Pair shall be powered by the shop power plug. The third rail shoes and propulsion systems shall be tested to ensure they are isolated from high voltage.

B. The plug shall be removed and power shall be verified to be routed back to the third rail shoes and isolated from the shop power receptacle. See T 9.04.01

20.12.02. Auxiliary Power Inverter (API) Tests

A. During start up, the API output shall ramp up voltage and frequency at a voltage/frequency ratio of 3.83 volts per Hz. See T 9.05.01

B. The API shall maintain an output voltage of 230VAC ±5% as all loads are powered on, one at a time. See T 9.10.03

1. The test shall be repeated with the supply voltage set to 400 and then 800 VDC.

a. The voltage or frequency shall return to the steady-state value within two seconds after an input voltage step change of 100 volts or a 50% step change in the output current. See T 9.10.03

b. The steady-state frequency regulation shall maintain an API frequency of 60 Hz, ±2 Hz.

c. The system shall maintain a phase-to-phase voltage imbalance of 1% or less on the 230 VAC subsystems See T 9.10.03

d. The API AC output waveform shall not exceed 5 % total harmonic distortion. See T 9.10.03

e. The efficiency of the API shall be at least 85% over the output power range of 20% to 100% of full load.

C. The API output voltage droop shall be less than 20% under worst case motor startup. See T 02.02.11

D. The API shall be observed to operate without lockout with intermittent third rail power, as may occur with closely spaced third rail gaps, rain and ice or rust on the third rail. See T 02.02.11

E. The failure of each API in a married pair shall be forced, one at a time. It shall be observed that essential loads are transferred to the other API.

F. With one API powering all essential loads, the API output voltage shall meet specified tolerances for steady state and for start-up droop.

G. The other API shall be restarted. It shall be verified that the loads are transferred back to the original inverter in a break before make switching arrangement. At no time shall the outputs of the two APIs be connected.

H. All circuits off the 230 volt power supply shall be separately ground fault tripped and reset. See T 9.05.08 These include:

1. Cab heaters/blowers

2. Convenience outlets in the cab and passenger interior. See T 14.02.23

20.12.03. Low Voltage Power Supply (LVPS) Testing

A. The LVPS shall maintain its output battery charging voltage within the battery manufacturer's recommended values. See T 9.10.01

1. The voltage shall be monitored as supply voltage varies from 400 to 800 VDC.

2. The droop characteristic shall be limited to 1 volt as the load is varied from 20% to 100%.

3. The efficiency of the LVPS shall be at least 80% for output power from 20% to 100% of full load.

4. The LVPS shall limit transients to ±10% of nominal voltage as a result of any step load change with the battery connected. The maximum overvoltage shall not exceed 42 Volts.

B. With the batteries disconnected, The LVPS shall limit the voltage peak to peak ripple to 3% or less of nominal.

C. A Failure of the API shall be simulated to ensure it does not affect the operation of the LVPS. See T 9.05.01

D. A failure of one LVPS in a Married Pair shall be simulated to ensure that all loads transfer to the operational LVPS. The single LVPS shall carry all loads within the Married Pair under the worst case supply voltage. No damage or overheating shall occur. See T 9.06.05

20.12.04. Ground Brush

20.12.05. The Contractor shall prove, through dynamic testing, the effectiveness of the ground brush system in preventing return current from flowing through the gear box low speed bearings and the truck journal bearings. Dead Battery Start

A. The contractor shall prove that the Dead Battery Start-up feature functions as agreed to during the design review.

20.13: PROPULSION SYSTEM QUALIFICATION TEST ON PILOT CARS

20.13.01. Emergency Propulsion Shut Down Time

A. When the Emergency Trainline is opened , the vehicle shall be tested to ensure:

1. Traction power is removed within 60 milliseconds and IGBT gates are blocked. See T 2.02.08

2. The Line Contactors open. See T 10.13.06

B. It shall also be verified that propulsion logic monitors the Emergency Brake Pipe pressure and shuts down propulsion when the pressure drops below 80 psig. See T 10.10.02

20.13.02. Safety discharge

A. A failure of the brake chopper shall be simulated to ensure that the filter capacitors bleed down to 50 volts within three minutes. See T 10.17.03

20.13.03. Trainline Conflict

A. Conflicting trainline commands for power or brake shall be simulated to ensure that a jerk limited transition to a full service brake occurs. See T 10.17.04

20.13.04. Load Compensation

A. A failure of the Load Weigh sensor shall be simulated to ensure that propulsion and braking default to the efforts below:

1. AW0 in traction and AW3 in braking.

2. No failure of the load weigh system shall cause a service or emergency braking effort to be less than AW0 effort.

B. The vehicle traction and braking systems shall ignore oscillations in air spring pressure due to vehicle motion. See T 10.08.02

20.13.05. Dead Rail Sensing

A. An unbridgeable third rail gap shall be simulated to ensure:

1. All input filters on the car are disconnected from the line. See T 10.04.10

2. The propulsion system inhibits power regeneration into the rail within 250 milliseconds. See T 10.04.10

20.13.06. Interlock Verification Tests

A. It shall be verified that traction power is removed and brakes apply after: See T 10.10.02

1. The Door Summary Circuit is opened.

2. The Emergency Brake Pipe pressure drops below 80 psig.

3. Direction commands are the opposite of train direction.

20.14: BRAKING SYSTEM QUALIFICATION TESTS T ON PILOT CARS

20.14.01. Emergency and Full Service Brake Tests

A. Emergency brakes shall be demonstrated to be an irreversible fail safe brake application that occurs on all cars in the train during any of the following conditions:

1. When the Emergency Brake Pipe trainline drops below 80 psig.

2. Opening or loss of integrity of the Emergency Trainline shall cause the removal of power to all Emergency Magnet Valves beyond the break and evacuation of the Emergency Brake Pipe. See T 12.02.06

3. Accidental uncoupling between any two cars in the train shall vent the Emergency Brake Pipe. See T 12.02.06

4. Activation of any trip cock in the train-set. See T 12.02.06

5. Activation of the Operator's Emergency Brake Pushbutton. See T 12.02.06

6. Operation of any/all Passenger Emergency Stop levers. See T 12.02.06

B. Full Service Brake shall be initiated by

1. Operation of any side door manual releases.

2. Interruption of the Door Summary Loop.

C. Emergency Brake applications shall be verified to comply with the following:

1. Opening the Emergency Trainline shall cause an immediate emergency brake application. Brake cylinder pressure on all trucks shall rise to 90% of emergency brake level within 800 milliseconds with the emergency magnet valve on the lead car blocked.

2. With electrical propagation disabled, the Emergency Brake Pipe pressure measured at the last car of a 6 car train shall drop to 10% of initial pressure within 1.8 seconds of activation of a single trip cock on the lead car.

D. The charging and maintaining valves shall maintain the Emergency Brake Pipe pressure at 110 psig. See T 12.02.06

1. Charging of the Emergency Brake Pipe may only take place when the train is at zero speed, the Master Controller is in Full Service Brake and the Automatic Train Protection (ATP) module on the controlling car permits it (or is bypassed). See T 12.02.06

20.14.02. Miscellaneous Brake Tests

A. It shall be possible to readily and positively distinguish between a brake applied and a released condition at the tread brake unit by visual inspection during a walk-by of the vehicle. See T 12.02.10

B. Passenger Emergency stops shall require no more than 20 lbs (89 N) of force to initiate emergency brake and to unlock the respective door. See T 14.02.20

20.14.03. Parking Brake Tests

A. Parking Brakes shall be fully proven to comply with the specification.

1. The parking brake shall apply whenever a direction is not selected from the Master Controller. See T 12.02.12

2. The parking brake shall have an interlock that prevents the train from developing positive propulsion unless all parking brakes are released. See T 12.02.12

3. Application of the parking brake, either by evacuation of release air or mechanical re-application after a mechanical release, shall cause the parking brake indicator light on the side of the car to illuminate. See T 12.02.12

B. The Parking Brake mechanical release shall be tested to prove:

1. It can be manually operated from locations inside the car as well as outside of the car without the aid of power or air pressure. See T 12.02.12

2. Activation of the mechanical release shall be clearly visible from outside the car. See T 12.02.12

3. Application of normal air pressure shall disable the mechanical release and return the parking brake to normal spring apply/air release operation. See T 12.02.12

4. A means shall be provided for re-applying parking brakes after mechanical release when no air pressure is available. See T 12.02.12

5. Both the interior and exterior parking brake mechanical release and re-apply mechanisms shall be operable by a 5th percentile female. See T 12.06.10

20.14.04. Snow Brake Tests

A. The following tests shall qualify the Snow Brake System functionality. The tests shall be performed with the use of a golden shoe (shoe fitted with a load cell): See T 12.06.05

1. When the FBCU reads the snow brake trainline active, it shall control brake cylinder pressures to apply a minimum pressure even when a complete brake release is requested.

2. The pressure shall be just sufficient to prevent the build up of snow and ice between the brake shoe and the wheel and to keep the wheel brake interface clean and dry, but prevent excessive wheel temperatures from occurring.

3. The final pressure setting shall be determined during pilot car On-Site Qualification testing. See T 20.20.32

4. The snow brake pressure setting shall be coordinated with the All Brakes Released function so that the snow brake application will not influence the operation of the All Brakes Released Trainline.

5. When the Master Controller in the controlling cab is keyed off, the snow brake function shall be disabled. See T 12.02.13

20.14.05. Trip Cock And Brake Cutout Tests

A. There shall be a cutout for de-activation of the trip cock.

1. The trip cock cutouts located undercar and those accessible from inside of the car shall be tested.

2. Cutouts at both locations shall be proven to reset when cleared at either location. See T 12.02.11

B. Activation of the trip cock shall be sensed with a limit or proximity switch and reported to the Vehicle Monitoring System. See T 12.02.11

C. Activation of any BCO shall be clearly visible at both the interior and undercar cutouts. Cutouts activated at the interior or undercar may be reset at either the interior or undercar location. See T 12.02.14

D. Activation of any BCO shall be demonstrated to be reported on the Vehicle Monitoring Display. See T 12.02.14

20.14.06. Air Compressor & Air Volume Tests

A. The successful operation of the trainline network control system provided to distribute compressor operation evenly among all compressors on the train shall be demonstrated. See T 12.05.02

B. The time required to charge the Emergency Brake Pipe of a 6 car train shall not exceed 10 seconds. See T 12.06.02

C. Failure of an air compressor shall be verified to display on the VMD. See T 12.05.02

D. Failure of a compressor or its output hose shall not vent the Married Pair Main Reservoir. See T 12.05.02

E. Air shall be supplied to the Supply Reservoir by the Main Reservoir with protection against loss of air pressure by means of a suitable check valve located in the Supply Reservoir inlet. See T 12.05.03

20.15: COMMUNICATIONS SYSTEM QUALIFICATION TESTS ON PILOT CARS

20.15.01. Audio Operational Test

A. Verify proper routing, volume levels and that the system is free of noise and distortion.

1. Frequency Response Test: Determine frequency response of all transmission paths, including PA, and crew intercom and PEI, by transmitting and recording audio tones. The test results shall meet the frequency response requirements of IEEE Std 1477-1998 between 100 Hz and 8000 Hz.

20.15.02. Signal-to-Noise Ratio Test

A. Measure signal-to-noise ratio of complete system at normal gain setting as follows:

1. Disconnect speaker microphone and replace it in the circuit with a signal generator using a 1000 Hz signal. Measure signal-to-noise ratio at internal and external PA speakers. The minimum acceptable ratio is 35 dB.

20.15.03. Distortion Test

A. Measure distortion at normal gain settings and rated power. Feed signals at frequencies of 200, 400, 1000, 3000, and 8000 Hz into each paging and PA amplifier, and a minimum of 2 selected intercommunication amplifiers. For each frequency, measure distortion in the amplifier outputs. Maximum acceptable distortion at any frequency is 2 percent total harmonics.

1. Acoustic Coverage Test: Feed pink noise into the system using an octave centered at 4000 Hz. Use a sound level meter with octave band filters to measure the level at the height specified in IEEE STD 1477-1998 section 4.2.5 throughout the car. Maximum permissible variation in sound pressure level is ±3 dB.

2. Power output Test: Measure electrical power output of each PA amplifier at normal gain setting at 1000, 3000 and 8000 Hz. Variation in power output at these frequencies shall be in accordance with IEEE Std 1477-1998.

3. Automatic Station Identification Test: Verify that the Automatic Station Identification tag reader correctly reads all tags and that the proper announcements are made at each tag.

4. AACP/AASCS Operational Test: Verify the ability of the AACP/AASCS to select and change route destinations, change destinations on destination signs, control and select automatic and pre-recorded announcements.

   a. Verify that voice and text messages are synchronized.

   b. Verify that text messages are displayed long enough to be readable and that they can be displayed in the time between stations or during station stops.

   c. Verify that Automatic Route Signs function as specified.

20.15.04. VMS Reporting Test

A. Demonstrate that communication system failures are reported to the VMS and displayed on the Vehicle Monitoring Display (VMD).

B. Demonstrate that communication system faults are recorded by the VMS.

C. Demonstrate that PEI requests are reported to the VMS and correctly displayed on the VMD with the car number of the requesting car.

20.15.05. Network Video Recorder (NVR), CCTV Camera Test

A. Demonstrate that cameras capture a complete view of the passenger compartment interior and of PEI stations and doors.

B. Demonstrate that each camera can deliver MPEG 4, Part 10 compressed video in real time to the NVR.

C. Demonstrate that the correct camera view is displayed on the cab video monitors in the cab configured for door control when:

   1. Any PEI pushbutton is activated.

   2. Any Passenger Emergency Stop is actuated.

D. Demonstrate that the controlling cab video displays are not active when the vehicle is in motion.

E. Demonstrate that camera views can be transmitted over the HDDR upon request (OPTION).

20.15.06. Train Radio Test

A. Demonstrate ability to communicate with an Authority provided hand-held or other radio from each radio in the train.

B. .

C. Demonstrate that the train radio speaker output will automatically be connected to the PA system upon receipt of a command over the radio data channel.

20.15.07. Communications Systems Fault Log Tests

A. Demonstrate the ability of the Portable Test Unit to access and display fault logs from all communications system intelligent devices.

20.15.08. Wayside Worker Warning System (WWWS) Test

A. Demonstrate two-way communication with the wayside units.

B. Demonstrate operation of the alerter.

C. Demonstrate that a failure of the WWWS is displayed on the VMD.

20.16: INTERIOR/EXTERIOR COMPONENT QUALIFICATION TEST ON PILOT CARS

20.16.01. Seat and Cantilever Tests

A. Seats shall be retested per the requirements of T 14.05.02 to ensure that the sidewall structure suffers no deformation or damage as a result of the forces imparted from the seat tests.

20.16.02. Stanchions, Handrails and Hand Hold Strength Tests

A. The following load tests shall be applied to the center of the span of each unique installation of stanchions and hand rails. All loads shall be applied normal to the surface. The loads shall not result in permanent deflection: See T 14.02.02

1. Stanchions 350 lbs (1557 N)

2. Hand Rails 350 lbs (1557 N)

3. Hand Loops 300 lbs (1335 N)

4. Hand Straps 200 lbs (890 N)

20.16.03. Windscreen Tests

A. Windscreens shall resist the following loads without suffering from permanent deformation: See T 14.02.06

1. A 250 lb (1112 N) load shall be applied over a 3 in x 5 in (75 mm x 125 mm) surface area at the center of the screen.

2. A 350 lb (1557 N) force applied in any direction at any location on the windscreen stanchion.

20.16.04. Side and End wall Liner Tests

A. A 20 lb (89 N) load distributed over a .5 in (13 mm) x .5 in (13 mm) surface area applied anywhere on the surface of the panel shall not cause the panel to deflect more than 1/8 inch (3 mm). Upon removal of the load, the panel shall return to the original position without signs of damage or permanent deflection. See T 14.02.15

B. A 50 lb (222 N) load uniformly distributed over a 6 in (152 mm) x 6 in (152 mm) surface, applied anywhere on the liner, shall not cause any damage or cracking.

20.16.05. not used

20.16.06. Signage Qualification Tests

A. Signs shall be tested to ensure compliance with the specification. See T 14.02.24

1. Per APTA RT-S-VIM-021-10, HPPL material shall emit 80.7 milli-candelas per square foot (7.5 milli-candelas per square meter) for 1.5 hours after loss of power.

2. The LLEPM shall be in compliance with APTA RT-S-VIM-022-10, Standard for Low-Location Emergency Path Marking for Rail Transit Vehicles.

3. Emergency access labels shall conform to retro-reflectivity requirements of APTA RT-S-VIM-021-10, Standard for Emergency Signage for Rail Transit Vehicles.

20.16.07. End Door Testing

A. The No.1 hinged end door shall be forcefully opened to test the heavy duty bumper/hold open device. No damage to the cab interior shall result from the impact of the door against the bumper. Manual closing shall be possible by a simple lever or a tug on the door. See T 14.03.04

B. All end doors shall energize the local vestibule light when opened. See T 14.03.04

C. The force to slide the No. 2 end door (and No. 1 Non-Cab Car end door) completely into the pocket shall not exceed 5 lbs (67 N). See T 14.03.16

20.16.08. Exterior Loop Step Strength Tests

A. A 400 lb (1780 N) load shall be applied at a 45 degree angle to the step, uniformly distributed across a 3 inch (76 mm) span of the step. Each step shall be tested. Load shall result in no permanent deformation. See T 14.03.06

20.16.09. Exterior Grab Handle Strength Tests

A. All handles and the carshell attachment points shall resist a 300 lb (1334 N) point load applied anywhere along the handle, with no permanent deformation. See T 14.03.08

20.16.10. Inter-Car Barrier Clearance Tests

A. The contractor shall demonstrate that barriers sufficiently close the gap between ends of cars but still allow Authority staff to easily enter the train through inter-consist end doors. See T 14.03.11

20.17: ATP/ASR QUALIFICATION TESTS ON PILOT CARS

20.17.01. Departure Test

A. The ATP shall be able to perform a Departure Test.

B. The Departure Test shall consist of two portions, each of which shall be initiated by the operator from the ADU with the train at rest in an area with no cab signal.

1. Cycle Test Portion

   a. The Master Controller must be in the Full Service Position.

   b. The ATP zero speed detection must be true.

   c. The Departure Test Indication on the ADU shall be illuminated.

   d. The ATP test circuitry shall vitally and sequentially generate a coded carrier for each signal aspect and inject the coded carrier into the test winding of the receiver coil.

   e. The ATP shall interpret the coded signal and display the aspect on the ADU.

   f. If all aspects are correctly recognized, the ADU shall inform the operator that the "Cycle Test Passed", otherwise "Cycle Test Failed" shall be displayed.

2. Brake Test Portion

   a. The Departure Test indication on the ADU shall be illuminated.

   b. The Master Controller must be moved to the Minimum Brake position.

   c. The ATP test circuitry shall vitally simulate a speed between the Overspeed Limit and Emergency Overspeed Limit.

   d. The Operator shall be able to observe the application of service or full service brake from the console gauges, depending on the operating mode.

   e. After the brake assurance delay, the Operator shall be able to observe a drop in emergency brake pipe pressure as the Emergency Brakes are applied.

C. Performance of the Departure Tests shall reset a 24 hour clock. If the 24 hour clock expires the ATP shall send a fault to the Vehicle Monitoring Unit. The fault shall be displayed to the operator.

20.18: EVENT RECORDER QUALIFICATION TESTS ON PILOT CARS

20.18.01. On-board system integration test

A. On-board system integration test shall demonstrate the Event Recorder’s interface compatibility and operational capability to record all required data correctly and to correctly record simulated failure events.

B. The on-board system integration test shall also demonstrate the ability to retrieve and display data as specified.

20.19: VMS QUALIFICATION TESTS ON PILOT CARS

20.19.01. Vehicle Monitoring System Test

A. The Contractor shall apply the functional portion of the VMS Qualification Test on the Pilot cars. Test shall be performed in accordance with T 16.09.

B. The test shall verify all features and components are in compliance with the specification.

1. Verification that all faults that are configured for all sub-systems to be displayed on the VMD are displayed properly.

2. Verification that all faults that are configured to be reported to the VMU are so reported.

3. Verification that fault logs of all systems in the train are accessible from the maintenance screen of the VMD in any cab in the train.

4. Verification that the software version numbers on all non-communications subsystems in the train can be accessed from the VMD of any cab.

5. Verification that all software changes made as a result of the VMS Factory Qualification Test have been implemented on all systems connected to the VMS.

20.20: ON-SITE QUALIFICATION TESTS ON PILOT CARS

20.20.01. General Requirements

A. All On-Site Qualification Tests shall be performed on the Authority's property. Failures after vehicle arrival shall be addressed by the Contractor. Acceptance of the Pilot Cars for testing purposes does not relieve the Contractor from issues arising during tests.

20.20.02. Mechanical Towing Compatibility with Existing Cars

A. The contractor shall demonstrate mechanical coupling between new cars and the Authority's existing vehicles. Electrical heads of the new cars shall not advance and no electrical connections shall be made between the cars. The towing pin shall be demonstrated.

B. #14 Orange Line married pair shall be coupled to married pairs of the existing #12 Orange Line cars. See T 4.01

C. The #4 Red Line married pair shall be coupled married pairs of existing #1, #2 and #3 Red Line cars. See T 4.01

20.20.03. Vehicle Compatibility Tests with Authority Equipment

A. The jacking pad locations shall be verified to be compatible with Authority's hoists. See T 2.01.05

B. The interface between the truck mounted vehicle equipment and the Authority's wheel truing equipment shall be checked for clearance and compatibility.

20.20.04. Dynamic and Friction Full Service Brake Tests

A. Braking shall be tested to ensure compliance with the following:

1. Dynamic Full service Brake rates at AW0 and AW3 shall be 3.0 mphps, +/- 5%, from 40 mph down to approximately 3 mph on level tangent track.

   a. Blending is acceptable above 40 mph depending on load weight, but the rate shall be maintained at 3.0 mphps, +/- 5%)

2. Friction only braking on an AW3 car shall maintain an average 2.75 mphps +20%/-10% brake rate from 60 MPH to standstill.

3. Brake shoe and wheel temperature limits shall be monitored during friction only braking to ensure limits are not exceeded during the test. No damage to the brake equipment or wheels shall occur as a result of 2 days of friction only braking.

B. Jerk limits during the tests above shall be limited to 2 mphps +/- 10% (unless the Authority selected a different, software adjusted jerk rate).

C. Dead time before a jerk limited response to a request for change in rate of deceleration shall meet the requirements of T 02.02.05.

D. Failure of the load weigh system shall result in braking effort corresponding to an AW3 load weight. See T 12.02.08

E. The Minimum Brake rate with Dynamic brake shall be 0.35 mphps, +/- 0.1 mphps.

20.20.05. Emergency Brake Tests on a 6 car train-set

A. An emergency brake request shall be triggered by opening the Emergency Trainline in an AW3 loaded 6-car train.

B. Within 60 milliseconds of removal of energy from the Emergency Trainline, the traction inverter shall be shut down and the Traction Unit Line Contactor shall open.

C. Brake cylinder pressures on all trucks in a train shall reach 90% of emergency brake pressure within 800 milliseconds.

D. Emergency Brake rates shall be verified to be 3.25 mphps + or - 20%.

E. Emergency brake rates shall be measured with AW0 and AW3 trains. The emergency braking shall be initiated with a wayside trip. The brake rates shall be calculated from the braking distances as specified in T 02.02.08.

20.20.06. Efficiency

A. Regenerative braking shall be able to return to a fully receptive line (between 530 and 700 volts) no less than 65 % of available kinetic energy, when decelerating an AW3 Car from 50 mph (80.5 km/hr) down to 5 mph (8 km/hr). See T 10.13.05

20.20.07. Propulsion System Tests

A. For passenger loading conditions from AW0 to AW2, the acceleration rate of a Married Pair shall be 2.75 mphps +/-5% (after jerk limited start) up to a speed of 16.3 mph +/- 0.2 mph. See T 02.02.02

B. System efficiency shall be measured and ensured to be 80% or higher. See T 02.02.02

1. Propulsion line current shall not exceed 1060 amps (1080 amps for the Red Line).

2. Acceleration rate shall be met, up to the line current limit, with third rail voltages between 530 and 600 volts and car weight of AW2.

C. For passenger loading conditions from AW0 to AW2 and line voltage at 600 VDC, the time to reach the following vehicle speeds shall be:

1. 10 mph in 4.4 seconds

2. 20 mph in 8.2 seconds

3. 30 mph in 13.9 seconds

4. 40 mph in 23.5 seconds

5. 55 mph in 55 seconds

6. 60 mph in 75.1 seconds

D. Response times for change in rate of acceleration shall be 150 ms or less. Changes from acceleration to deceleration shall be 300 ms or less.

20.20.08. Braking Resistor Temperature Rise Test

A. The resistors shall have the capacity to provide power dissipation during operation at full service rheostatic-only braking over the complete Orange and Red Lines with AW3 loading and with regeneration cutout. The test shall include station stops, but no dwell. Temperatures shall not exceed safe operation limits, trigger an over temperature shutdown, or suffer any damage to the brake resistors, resistor mounting hardware or brake chopper components. Tests shall be completed with ambient temperatures above 75°F (23.9°C). See T 10.04.06

20.20.09. ATP/ASR Aspect Enforcement Tests

A. Verify that violation of the Overspeed Limit results in an immediate brake request.

B. Verify that violation of the Emergency Overspeed Limit results in an immediate emergency brake request and a shutdown of the traction inverters. This shall be validated for each signal aspect.

C. Verify that exceeding the Overspeed Limit:

1. Initiates a 2.2 mphps service brake request when the ATP/ASR unit is in ASR mode and a full service brake request when the ATP/ASR unit is in Manual mode.

2. Causes the overspeed indicator on the ADU to flash when the ATP/ASR unit is set in ASR mode.

3. Causes the overspeed alarm to sound when the ATP/ASR unit is set in Manual Mode.

   a. Failure to move the Master Controller to Full Service Brake position within 2.5 seconds of an alarm will result in an irretrievable full service brake to stop.

4. Causes an emergency brake application if no minimum brake assurance rate is met within a preset time or if the requirements of the brake assurance banking algorithm are not met.

20.20.10. ATP/ASR Test of Operational Modes

A. Tests shall ensure that Manual Mode Operation results in: See T 15.02.12

1. Master Controller requests for power and braking are not modified by the ASR system.

2. Audible alarms and flashing ADU when the train is overspeed.

3. Full service brakes will automatically stop the vehicle unless the Operator responds to the overspeed within 2.5 seconds by moving the master controller to the full service brake position.

4. Emergency brakes will stop the vehicle if the brake assurance rate is not met within the preset time limit established during design review with the Authority.

B. Tests shall ensure that Manual Release Mode and the Hostler Release Mode both result in: See T 15.02.12

   1. Manual Release (or Hostler Release) is displayed on the ADU.

   2. 10 mph speed limit.

   3. Flashing ADU when overspeed.

   4. Operations Control Center receives a message indicating Manual Release (or Hostler Release) has been selected.

C. It shall be demonstrated that the ATP does not read any wayside signal command unless the Master Controller is in the forward position.

D. It shall be demonstrated that when the ATP is in the Manual Release or Yard 10 mode that the Manual Release or Yard 10 mode is cancelled when any valid code is received for Orange Line cars. These modes shall be demonstrated to be cancelled when any valid code greater than a stop code is receive for Red Line cars.

E. Emergency Bypass Operation shall result in:

   1. Emergency bypass is displayed on the ADU.

   2. 25 mph speed limit, enforced by the ASR (No flashing of ADU when overspeed).

   3. Operations Control Center receives a message indicating Emergency Bypass has been selected.

   4. The Emergency Bypass Light on the exterior of the car (normally on) shall extinguished.

F. Normal/Reserve Operation: See T 15.02.13

   1. Verify that the controlling ASR can be selected by placing the Master Controller in the Full Service Brake position and selecting Normal or Reserve on the ADU switch.

   2. Verify Hot Standby Functionality.

20.20.11. Overspeed and Emergency Overspeed Response Time Verification

A. Verify that the ATP reacts to the following conditions within the time stated: See T 15.03.03

   1. Overspeed detected within 100 ms.

   2. Brake application initiated within 100 ms of Overspeed detection.

   3. Emergency Overspeed detected within 100 ms.

4. Emergency brake application initiated within 100 ms of Emergency Overspeed detection.

5. Emergency brake application initiated with 100 ms of an emptied Brake Assurance Bank.

20.20.12. Overspeed Limits

A. The Overspeed Limit shall be tested to ensure it is set 1.0 mph above the nominal speed. See T 15.03.05

B. The Emergency Overspeed Limit shall be tested to ensure it responds based on the limits listed in table 15-3. See T 15.03.06

C. It shall be verified that exceeding the overspeed limit shall not cause an emergency brake application if the brake assurance rate is already met.

20.20.13. Brake Assurance Rate

A. A test shall be run to verify that failure to achieve a minimum brake assurance rate will initiate an emergency brake in 2.8 seconds (software adjustable).

B. Brake Assurance Banking shall be tested to verify that the algorithm safely enforces a cumulative average brake rate of 1.6 mphps. The Brake Assurance Banking algorithm shall be demonstrated to limit the need for emergency brake applications during slides and slide corrections.

20.20.14. Spin/Slide Control Capability

A. A wheel spin shall be initiated during acceleration by preparing the rail, if necessary, with a soap solution, or equivalent. See T 10.08.04

   1. When the spin commences, power shall be reduced until the spin is corrected. Power shall be reapplied automatically when the spin is corrected under jerk-limited control.

B. Wheel slide shall be initiated during service braking on rail conditioned as above. The slide control system shall coordinate dynamic and friction braking in a manner that:

   1. Prevents wheel damage, particularly flat spots.

   2. Effectively maintains a brake rate of at least 1.6 mphps even if some controlled sliding is required.

C. A speed sensor failure shall be simulated during braking. The slide control system shall be observed to ignore that speed sensor for determining slides.

D. A test shall be conducted to verify that the Friction Brake System detects a slide control valve stuck in the release position. The Friction Brake System shall also be verified to report this failure as Friction Brake Failure fault on the VMD and lock out slide control on the affected truck until the friction brakes are serviced.

E. Tests that initiate wheel slides shall be performed on a Married Pair basis, unless otherwise indicated.

20.20.15. Test of Slide Control During Emergency Braking

A. Wheel slide control shall be verified to be locked out for emergency brake application initiated by ATP, Emergency Mushroom Switch or trip cock unless lockout bypass jumpers are installed.

B. Emergency brakes shall be applied with the rail conditioned as above to create a slide.

C. A review of the results of these tests shall be used by Authority together with the Slide Control FMECA to determine under which if any modes slide control will be permitted to be active in emergency braking.

20.20.16. Air System Tests

A. The air system on the vehicles shall be dynamically tested to ensure compatibility with the specification:

1. One air compressor shall be able to supply all air needs of a 4-car train in normal service without overheating or suffering any damage. See T 12.06.07

2. With air from the Supply Reservoir only (Main Reservoir feed cut off) and 130 psig initial pressure, it shall be possible to make five full service brake application/release cycles of 10 seconds apply and 30 seconds release, at a vehicle weight of AW3. See T 12.06.07

   a. After the 5 service brake applications, sufficient capacity shall remain to make one AW3 emergency brake application. See T 12.06.07

3. The Main Reservoir shall have sufficient capacity for simultaneous operation of the friction brakes and all other pneumatic devices on the car (including leveling valve cycling due to load variations). See T 12.05.03

4. The time to 90% reduction of the Emergency Brake Pipe pressure in the last car of 6-car train shall not exceed 1.8 seconds when vented by pneumatic propagation only. See T 12.06.02

20.20.17. Roll Back Tests

A. The roll back feature shall allow for an AW3 train, with half the motors cut out, to start on a 4% grade without rolling back. See T 12.03.02

B. A roll back shall be created to verify that, after 25 degrees of wheel rotation, a roll back fault shall be declared and full service brakes shall be applied. See T 12.03.02

C. The propulsion system shall be cut out to inhibit traction power on 4% grade. A roll back shall not result. See T 12.03.02

D. Roll back prevention shall be verified during a test where the All Brakes Released Trainline is active on a 4% grade and traction power is suddenly removed on all cars. See T 10.08.03

20.20.18. Inching Switch Test

A. The Inching Switch, (located on the back side of the Operator's console, in front of the windshield), shall be verified to be easily and safely accessible by a 5th percentile female and a 95th percentile male Operator standing in front of the windshield.

B. The Master controller shall be placed in full Service Brake and the inching switch shall be depressed. The vehicle shall inch forward until coupling occurs.

C. The Switch shall be placed in the coast position, causing the car to coast.

D. Releasing the Switch shall be verified to initiate a full service brake. See T 05.03.02

E. It shall be verified that the Inching Switch cannot be activated when the Master Controller is in positions other than Full Service Brake.

20.20.19. Parking Brake Hold Test

A. The Parking Brake shall be tested to verify that it holds an AW3 loaded Married Pair on a 6% grade in dry rail conditions and a 4% grade in wet rail conditions.

20.20.20. Collector Shoe Special Tools Testing

A. Special tools located in the cab shall be tested to ensure the design provides a safe, functional device that allows for lifting and securing the collector shoe. See T 5.04.07

20.20.21. Coupler and Draft Gear Clearance Test

A. The first two Married pairs shall traverse the entire right of way, including all yard track, to verify the following:

1. Sufficient slack shall be present in all clamps, cables, hoses and wiring so that no damage occurs and the minimum bend radii of the components are not exceeded.

2. Clearances of T 02.01.05, Vehicle Design Requirements, Clearance, shall not be violated anywhere along the right of way.

20.20.22. Headlight and Inter-Car Barrier Verification

A. During the clearance test above, the inter-car Barriers shall be verified to be quiet and trouble free throughout the right of way. See T 14.03.11

B. The low beam headlight angle shall be checked to ensure glare observed by the drivers of on-coming vehicles is acceptable.

20.20.23. Journal Bearing Over-Temperature Indication Test

A. A journal bearing over-temperature simulation shall be created to verify that the detection method provides an obvious, easily noticeable indication. See T 11.03.04

20.20.24. Trainline Tests

A. Test the Power/Brake Mode Trainline protection circuit by creating a disagreement between the mode requested and the P-wire loop. Propulsion and braking systems shall implement a full service brake application. See T 24.07.02

B. Request power and disable the All Brakes Released Trainline. Ensure that after the preset time delay elapses (as established with the Authority during design review), a trainline command for a full service brake is applied. See T 24.07.03

20.20.25. Vehicle Monitoring System Test

A. The test shall verify that faults created anywhere on a 6 car train-set, that are configured to be displayed on the VMD, are so displayed. Faults from each and every system shall be simulated and demonstrated to display properly.

B. Fault logs from all cars in the train-set shall be accessed from any cab.

C. Simulate fault data upload to the wayside as described in T 13.04.

D. Not used.

20.20.26. Noise And Vibration Tests

A. Overall noise levels shall be measured in dB on the A scale (dBA) with slow meter response setting for stationary vehicle measurements and fast meter response for moving vehicle measurements. Noise shall be measured in accordance with ANSI S1.4. Noise limits shall be measured to ensure compliance with the following:

1. With the vehicle stationary and all equipment running in revenue service conditions, the interior noise level shall not exceed 72 dBA.

2. At vehicle speeds up to 60 mph on above ground track, the maximum internal noise level shall not exceed 78 dBA.

3. In the subway sections of the right of way, the maximum internal noise level shall not exceed those of existing Red and Orange Line vehicles.

4. Noise external to the vehicle, while stationary, shall not exceed 70 dBA at a distance of 50 feet from the side of the vehicle.

5. Noise external to the vehicle, when measured 50 feet from the side of a train traveling at 60 mph and braking, shall not exceed 82 dBA.

6. Cab heater noise level in HIGH speed not to exceed 73 dBA, as measured at the centerline of the Operator seat, 3 feet (0.9 m) above bottom cushion.

20.20.27. Multiple Trainset Tests

A. An AW3 loaded 6 car train shall push and then pull an un-powered AW3 loaded 6 car train between any two stations, regardless of grade.

1. No damage, permanent deflection shall be caused on any coupler or vehicle component.

2. Audible coupler "slap" shall not occur under this condition. See T 4.03

B. Two Married Pairs shall be coupled at 3 mph (4.8 km/ hr) to ensure that no damage occurs to any coupler or carshell components, including the shear pins. See T 4.03.03

C. An empty 6 car train shall have the ability to push or tow an empty 6 car train the entire length of the Orange or Red Line. The test train shall travel at 10 mph through stations without stopping. No traction motors, traction inverter components or braking components shall exceed the towing duty temperature limits defined in TS10.04.01 and TS10.05.01, trigger an over temperature shutdown, or suffer any damage.

D. An AW3 Married Pair towing a dead AW3 Married Pair shall be kept to 15 mph down the longest grade on the Red or Orange Line with regenerative braking cut out. This test shall not result in triggering an over temperature shutdown, nor cause any damage to or overheating of the brake resistors, resistor mounting hardware or brake chopper components.

E. Verify all trainline components and networks are designed to ensure proper operation of trainlined functions for train lengths of up to 12 cars. See T 24.01

F. Ensure that communication controls and devices are available throughout all 12 cars when one 6-car train tows a disabled or dead train. See T 24.07

20.20.28. Model Validation Test

A. Upon completion of the Ride Quality Test specified in T 02.02.16, The Contractor shall perform a Model Validation Test to ensure that the assumptions and estimates used for the truck/carbody modeling accurately reflect the performance of the vehicle.

B. All results collected and submitted under T 11.11.04, Analyses Required, shall be verified on the Authority’s Right of Way (ROW). Verification of vehicle stability on the worst mainline and yard curves, switches, turnouts and general track conditions shall be provided. The following performance data shall be collected during the test.

1. Safety Against Derailment - Wheel L/V (resistance to wheel climb).

2. Safety Against Derailment - Truck side L/V (rollover potential).

3. Report of outputs and corresponding input criteria for the Net Axle Lateral Force (NAL).

4. Wheel Unloading - equalization under track superelevation, track alignment and

track perturbations resulting in raised and lowered wheel conditions.

C. High Speed Stability - performance up to 70 mph (or maximum posted speeds) throughout the ROW, with selected worst case combination of worn wheel, primary or secondary suspension condition.

1. Testing shall verify that there is an absence of hunting, or repeated oscillations without significant damping. See T 11.10.03

20.20.29. Reliability Testing

A. The Contractor shall perform the Pilot Car Reliability Test according to T 02.03.07 and the Fleet Reliability Demonstration Test according to T 02.03.08. Both test procedures shall comply with the Contractor's approved Reliability Demonstration Plan.

20.20.30. Train To Wayside Emission Limits Tests

A. Conductive, Inductive and Radiated emission limit testing shall be performed in accordance with the requirements of T 02.07.02.

20.20.31. 4 Season HVAC Test

A. The 4 season test is intended to verify the assumptions made in the climate room through actual in service conditions encountered during a full calendar year. Actual in service conditions may determine that modifications to the temperature control matrix or setpoints are needed. This test need not be completed prior to acceptance of pilot cars.

B. The Authority intends to collaborate with the Contractor to perform this test. The system has been designed to allow simple PTU setpoint changes. This test shall be an opportunity to modify setpoints in a controlled, documented manner.

C. Adjustments shall be considered refinements rather than changes. Adjustments will be captured as default setpoints on revised software versions.

D. Return, fresh and supply air temperatures, door openings and closings, air spring pressures (for passenger load estimations) and operating condition of the HVAC units and floor heaters shall be collected.

E. The Snow Brake shoe force setting shall be fine tuned during the winter season portion of this test. Ambient temperature during the test should be no greater than 15°F (-9°C).

20.20.32. Maintainability Qualification Testing

A. This test shall be performed to ensure that all components are easily accessible and maintainable as designed. It will also serve as a verification of the draft maintenance manuals.

B. All maintained items shall be removed and replaced by the Contractor. Time required shall be verified to be in accordance with T 02.04.04, Maintainability Demonstration, and the removal/replacement times listed in the specification.

C. Average time shall be calculated and verified to be in accordance with T 02.04.02 Mean Time to Repair (MTTR).

D. The Authority reserves the right to request a redesign if maintenance of any item requires removal of more than one adjacent component, requires the shifting of pipes or wires, or fails to meet the MTTR requirements.

20.21: PRODUCTION TESTS ON COMPONENT EQUIPMENT

20.21.01. General

A. The testing requirements of section 20.06 apply to all applicable components used on the Pilot Cars and all subsequent vehicles provided in this procurement.

B. Testing shall be performed to verify complete functional performance before equipment is shipped to the Contractor.

C. Test Reports shall be shipped with each component and included in the Car History Book.

20.21.02. Continuity (Ring out) Tests

A. Wiring continuity tests shall be performed, point-to-point, on all wiring of each component used in the construction of the vehicle as well as the final vehicle itself. Continuity tests shall also verify correct polarity.

20.21.03. Insulation Resistance (Meggering) test

A. Insulation resistance tests shall be conducted to verify the state of insulation of all wiring of each voltage class of all components and the final vehicle.

B. Semiconductor devices may be protected against high voltages by short circuiting or disconnecting some parts of the equipment. The Contractor or sub-supplier's test procedure shall document all equipment bypassed.

C. The values below represent the final insulation resistance for the vehicle. The Contractor shall determine appropriate portions for sub-systems so that the final vehicle results meet the requirements:

Nominal Circuit Voltage (Volts dc or ac rms) and minimum insulation resistance

Below 90 volts	2 megohms at 500 VDC
90 to 300 volts	4 megohms at 1000 VDC
Above 300 volts	5 megohms at 1000 VDC

20.21.04. Dielectric (Hi-Pot) tests

A. The dielectric test shall be conducted after the insulation resistance test is completed and passed. Tests shall be conducted to verify the state of the insulation to the case, conduit, raceway and vehicle carshell.

B. The wires in a system shall be shorted to ensure that all are tested and to prevent capacitive or fault currents from passing through and damaging low voltage devices.

C. The test shall be conducted by applying the test voltage shown below for a period of one minute. The test is passed if there is no insulation breakdown or arcing.

Nominal circuit voltage (DC or AC rms) and test voltage

Below 300 volts	2V + 1000 VAC rms
Above 300 volts	2.25V + 2000 VAC rms

(Note: V in the above equations is the operating Voltage of the circuit).

D. Tests shall be done in conditions that allow visual and auditory detection of short circuit arcs.

E. Repeated high potential dielectric tests shall be avoided. For repeated tests, the test voltage shall be 85% of the voltage stated above.

20.21.05. Water Test

A. Water tests shall be completed on each component exposed to the elements (either directly, as a result of wind driven rain, or through an open cab side window). Testing shall be a minimum of 10 minutes per component. Components that utilize fans shall be tested with fans operational.

1. The Authority may consider granting a waiver on cab interior components after the weather proof design is proven through an accelerated life cycle test.

2. Components that are installed on the vehicle and exposed to water testing at the car level may also be waived from this requirement on a case by case basis.

B. Testing shall provide the quantity and pressure of water per square foot as per the requirements of T 20.22.03, Water Test Requirements.

C. Equipment shall be completely dry internally and functionally intact after water test.

20.22: PRODUCTION TESTING ON ALL VEHICLES

20.22.01. General Requirements

A. All functions shall be verified on each car prior to the Contractor's request for shipment. The tests listed below should not be considered a comprehensive listing.

B. Test reports for all Production Tests on each Married Pair shall be included in the Car History Book.

C. All hour meters shall be read prior to vehicle delivery and included in the Car History Books.

20.22.02. Wiring Tests

A. The wiring tests documented in the Component Production Tests, T 20.04.04, shall be performed on each Married Pair.

20.22.03. Water Testing Requirements

A. Two water-tightness tests shall be performed on each car to confirm complete water-tightness. The first test shall be conducted on the carshell after installation of windows and before the installation of insulation. Refer to T 03.04.07 for additional details. The second test shall be conducted on the completed car.

B. The tests shall cover all surface areas of the roof, sides and ends with a water spray directed at the carshell, with full overlap between all spray nozzles. Water shall be sprayed from nozzles that are spaced no more than 3 feet (.9 meters) from, and aimed directly at the surface being tested. Not less than 1/2 gallon (1.9 liter) per minute shall be delivered to each square foot of surface being tested and the nozzle velocity of the water shall be not less than 150 feet per second (46 meters per second). All areas shall be sprayed for ten minutes before the inspection for leaks begins. Water shall be sprayed continuously during the inspection.

1. Underframe equipment water testing shall require the same water volume and duration, but shall be performed separately in a configuration that allows access for post test inspection.

C. Water entering the car shall be cause for rejection and a re-test after corrections are made. Caulking, or any other filler, shall not be used to facilitate the sealing of windows or any other component.

20.22.04. End Wall Water Tests

A. The No. 1 end door on the cab car shall be tested to simulate driving rain at revenue service speed See T 14.03.04. Nozzles described above shall be located 12 inches from face of the door and slowly moved around the perimeter of the door.

B. The windshield shall be suitably gasketed to be water-tight without the use of sealant. See T 05.02.06

C. End mask threaded inserts, headlights and marker lights shall be verified to be water-tight.

20.22.05. Side Wall Water Tests

A. Side doors shall preclude the entrance of water. Small amounts of water may puddle on the side door thresholds as long as it drains via the sloped threshold.

B. HVAC units shall be thoroughly tested with evaporator fans Powered.

1. HVAC condensate and rain water shall drain to the roof pan and be funneled through drain lines that terminate under the car, directing water to the track bed. Water shall not flow over the sides of the car, including times when the roof corrugations drain into the pan, as a result of train movement). See T 14.03.25

2. The HVAC air inlet openings shall prevent water from entering the unit or reaching the fresh air filters.

3. Rain gutters over the side doors, windshields and cab side windows shall prevent water from flowing in these areas.

20.22.06. Underframe Water Tests

A. Water testing shall be conducted on all underframe enclosures to ensure they remain completely dry. The following components, at a minimum, shall be verified to be water-tight:

1. Propulsion inverters, with cooling fans operational (if equipped).

2. Auxiliary Inverters, with cooling fans operational (if equipped).

3. Battery Box

4. Low Voltage Power Supply, with cooling fans operational (if equipped).

5. Drum Switch (if equipped)

6. Trainline Junction Boxes

7. All switches, sensors and miscellaneous components mounted under the car

8. The covers that protect uncoupled electrical heads shall be tested to ensure they prevent moisture ingress. See T 4.02.05

B. The automatic coupler heads between the first two Married pairs shall be water tested to ensure that rubber gaskets form a tight seal between coupled cars. See T 4.02.05

20.22.07. Coupler Functional Testing

A. The coupler and draft gear equipment shall be functionally tested on each married pair at the Contractor's facility. The test shall be comprehensive and sufficient to ensure proper operation of all components and functions.

B. The heater and activation indicator shall be verified to function properly. See T 4.02.05

20.22.08. Coupler Height Measurement

A. The height of the coupler center line, as measured from top of rail with secondary suspension at normal height and new wheels, shall be as shown below, with ±1/2 inch (12.7 mm) tolerance: See T 4.01

1. Orange Line: 2 feet, 6 1/4 inches (768 mm)

2. Red Line: 2 feet, 7 5/8 inches (803 mm)

20.22.09. Electrical Coupler Control Tests

A. Coupler controls installed on the cab console and the hostler panel shall be tested to ensure proper functionality. See T 4.02.09

   1. Once coupled to a like car, the operation of the Couple switch shall open the pneumatic trainline valves, advance the electrical heads and configure the trainlines as a coupled car.

   2. Operation of the Uncouple Trainline switch shall close the pneumatic trainline valves, retract the electrical heads and configure the trainlines as an end car.

   3. Operation of the Uncouple Mechanical switch shall mechanically uncouple the cars and engage the centering devices.

B. The electro-pneumatic control unit valves shall be verified to be functional with both electric and manual controls. See T 4.02.10

C. The uncouple solenoid valve interlocks shall be tested to ensure they preclude inadvertent uncoupling. See T 4.06.01

D. The trainline connections listed below shall be verified to be made when electrical heads have not advanced: See T 4.02.11

   1. Bell

   2. Battery Negative

   3. Train Ethernet Network

E. Married Pairs shall be uncoupled to ensure that the un-powered portion of the train is automatically placed in emergency brake. See T 4.06.01

20.22.10. Operator's Controls Testing

A. All devices, controls, switches and buttons shall be operated to ensure proper operation of the device, as detailed in the specification. The items tested, as a minimum, shall include:

   1. Master Controller See T 5.03.02

   2. Transfer switch See T 5.03.02

   3. 3 position direction switch See T 05.03.02

   4. 3 position, (Power-Coast-Brake) "Inching" switch See T 05.03.02

5. Operator's Console Switches See T 5.03.03

    a. Wiper
    b. Wash/Wipe
    c. Horn
    d. Emergency Stop
    e. Headlights
    f. Windshield Heater
    g. Interior Lights
    h. Cab Lights
    i. Aux. Cab Lights (including lighting within equipment enclosures)
    j. Cab Fan
    k. Cab Thermostat
    l. No Motion Reset
    m. Sleet Scraper
    n. Snow Brake
    o. Couple
    p. Uncouple Trainline
    q. Uncouple Mechanical
    r. Bell
    s. Lamp Test
    t. Console Lamp Dim
    u. Cab Ceiling Fan (if used)
    v. PA Talk
    w. Train Shut-Down
    x. Emergency HVAC Shut-Down
    y. Security Alert

z. Passenger Emergency Stop Reset

6. Bypass/Cutout Panel switches See T 5.03.04

   a. Truck One Propulsion Cutout

   b. Truck One Propulsion Cutout

   c. Truck Two Propulsion Cutout

   d. Non Cab Car Truck One Propulsion Cutout

   e. Non Cab Car Truck Two Propulsion Cutout

   f. Door Interlock Bypass

   g. No Motion Bypass Cab Car

   h. No Motion Bypass Non-Cab Car

   i. Regen Cutout

   j. Door Control Isolation Cab Car

   k. Door Control Isolation Non-Cab Car

   l. Air Compressor Cut-Out

   m. Brake Interlock Bypass

   n. Aux. Inverter Cab Car

   o. Aux. Inverter Non-Cab Car

   p. LVPS Isolation Cab Car

   q. LVPS Isolation Non-Cab Car

   r. Lighting Cutout - Cab Car

   s. Lighting Cutout – Non-Cab Car

   t. HVAC Cutout - Cab Car

   u. HVAC Cutout - Non-Cab Car

   v. Floor Heat Cutout - Cab Car

   w. Floor Heat Cutout - Non-Cab Car

B. All illuminated Console indicators shall be verified to energize when operation is requested. See T 5.03.05

a. Door Interlock Bypass (verify indicator in cab and on hostler panel)

b. No Motion Bypass (cab and hostler panel)

c. Regen Cutout

d. Sleet Scraper On

e. Snow Brake On

f. Parking Brake On (cab and hostler panel)

g. Heated Windshields On (cab and hostler panel)

h. Brake Fault (cab and hostler panel)

i. Doors Summary Loop (cab and hostler panel)

j. Passenger Emergency Stop

20.22.11. Circuit Breaker Panels (Cab and Non-Cab cars)

A. All Circuit Breakers shall be tested to verify intended loads are de-energized and properly re-energize when the breaker is cycled. See T 5.03.06

1. 600 volt Circuit Breakers (located under the car) shall be tested to verify intended loads are de-energized and properly re-energize when the breaker is cycled. See T 5.03.06

20.22.12. Bell Testing (activated from both Cab and Non-Cab cars)

A. The bell pushbutton shall energize the bell trainline and power all bells in the train-set.

B. Depressing the pushbutton in any cab shall energize bells in all cabs, regardless of Door Setup Switch Position. See T 5.03.08

20.22.13. Miscellaneous Audible Alarms

A. All audible alarms shall be tested to verify proper operation. See T 5.03.09

20.22.14. VMS System

A. Verify that all faults as agreed upon during the design review are displayed, real time, as they occur.

B. The screen shall be verified to be set to high contrast and verified to operate correctly. See T 5.03.10

20.22.15. Communication System Tests

A. Verify proper routing, volume levels and that the system is free of noise and distortion. Verify correct signage display. Verify that voice and text messages are synchronized. Test available message path from each PEI and crew intercom.

B. Verify that the Automatic Station Identification tag reader correctly reads a tag and that the proper announcement is made.

C. Demonstrate that the train radio speaker output will automatically be connected to the PA system upon receipt of a command over the radio data channel.

D. Demonstrate the communications system's ability to report faults to the Vehicle Monitoring System.

20.22.16. Communications Control Panel (Cab and Non-Cab cars)

A. The CCP functionality shall be fully tested (PA, Train Radio, PEI and Cab-to-Cab Intercom. See T 5.03.15

1. Gooseneck microphone, handset and hand held microphones shall be verified.

2. The proper operation and configuration of the 2 cab speakers, all interior and all exterior speakers shall be verified. See T 5.03.15

20.22.17. CCTV System Tests

A. The system will be verified by activating each Passenger Emergency Intercom (PEI), Passenger Emergency Stop, or other system set up to activate the CCTV system within the train-set, one at a time. The view that captures the device and surrounding area shall be displayed on the screen. See T 5.03.11

1. The lead cab shall be ensured to display the image only after the car has come to a stop.

2. All cabs with the Door Setup Switch in the ON position shall immediately receive the camera image when the device is energized.

B. Demonstrate that each camera can deliver MPEG 4 Part 10 compressed video in real time to the NVR.

C. Demonstrate that camera views can be transmitted over the HDDR upon request.

20.22.18. Duplex Air Gauges (Cab and Non-Cab cars)

A. Gauges shall properly display emergency brake pipe pressure, main reservoir pressure, truck No. 1 and truck No. 2 brake cylinder pressures. See T 5.03.13

20.22.19. Cutout Cocks (Cab and Non-Cab cars)

A. All cutout cocks in the cab, hostler panel area, passenger area (behind locked access panels) and undercar shall be verified to cutout the air line of the appropriate system or device and can be reset from both internal and external controls (if equipped). See T 5.03.14

20.22.20. Portable Test Unit (PTU) access port

A. All systems shall be interrogated from through their local PTU access port for serial number, software version and the settings of all variables. See T 5.04.06.A. Serial numbers shall be checked against those logged in the Car History Book.

B. All hour meters shall be read and recorded for information to be used during the Reliability Program Plan.

20.22.21. The Train Shut-Down switch

A. The Train Shut-Down switch shall be verified to reset the train and reboot all microprocessor based systems. All systems shall shut down and all connections to the battery (except emergency lights) shall be opened.

B. Keying the car back on shall re-energize the systems.

C. The Train Shut-Down switch shall be tested to ensure that its functionality is disabled whenever the car is keyed up. See T 5.03.17

20.22.22. Odometer Verification

A. A mechanical odometer shall be read and verified to match the reading shown on the propulsion system. See T 5.03.17

20.22.23. Operator's Seat Testing

A. The seat heater system shall be checked for proper operation. See T 5.04.02

20.22.24. Cab Interior Lighting

A. All cab interior lighting shall be energized and verified to function. See T 5.04.04

1. De-energizing the LVPS units shall not impact the emergency lighting fed cab lights.

20.22.25. Access panel lighting

A. Verify that lights energize when access panels are opened.

20.22.26. Convenience Outlet Tests

A. Outlets shall be verified to function and ground fault circuits shall be ‘tested’ and ‘reset’.

20.22.27. Special Tools, Stretcher, Ladder, Fire Extinguisher and Evacuation Chair Verification

A. Collector shoe special tools and emergency devices shall be verified to be securely installed in the cab.

B. The Non-Cab Car shall be checked for secure installation of the collapsible ladder.

C. Fire extinguishers shall be verified to contain a full charge.

20.22.28. Hostler Panel Testing

A. Functionality of the hostler panel and other controls fitted in the No. 1 end of the Non-Cab Car shall be tested and verified to comply with the specification. See T 5.05.02. At a minimum, the following shall be tested:

1. Transfer switch
2. Direction switch
3. Compact Master Controller
4. Duplex air gauge
5. Headlights
6. Horn
7. Couple
8. Uncouple Trainline
9. Uncouple Mechanical
10. Windshield heater
11. Windshield wiper
12. Bell
13. Emergency stop switch
14. All indicator lights

B. It shall be verified that the ATP system enforces a 10 MPH (16 km/hr) speed limit.

C. It shall be verified that engaging the emergency bypass switch in the cab car enforces a 25 MPH (40 km/hr) speed limit.

D. It shall be verified that the ASR switch correctly selects the Normal or Reserve Automatic Speed Regulation unit to be on line. See T 15.02.08

E. It shall be verified that all hostler controls, Train Radio, relays and the windshield heater are disabled when the transfer switch key is removed.

20.22.29. Primary Suspension Creep Correction Tests

A. One half the AW0 car load (or a load fixture set to the equivalent) shall rest on the primary suspension for 5 days. Height adjustments shall be made for creep. The test report shall identify the height adjustment required. See T 11.06.01

20.22.30. Car Level Verification Test

A. The car floor shall be leveled to the height established in T 02 and shall be leveled side-to-side and end-to-end. All tolerances are ±1/4 inch (6.4 mm). See T 11.06.03

20.22.31. Air System Test

1. The governor shall cut in at 130 ± 2 psig and cut out at 150 ± 2 psig.) See T 12.05.02

2. The safety valve shall be operated when the maximum system pressure of 160 psig is exceeded.

3. The operation of the water purge valve shall be ensured to function properly.

4. Leakage from the air supply system with a Married Pair set to max brake shall not cause a drop of more than 10 psig in 15 minutes, starting 5 minutes after the air compressor shuts off at 150 psig. See T 12.06.09

20.22.32. Truck Component Height Verification Test

A. The third rail shoe will be set to the proper height as shown in T 2, Vehicle Design Requirements. Spring tension shall be confirmed to match the Contractor's recommended value. See T 11.04.04

B. Trip cocks shall be verified to be set at the proper height.

20.22.33. Married Pair Brake Test

A. Married Pair brake test at the Contractor's facility shall test all brake and emergency brake functions, pressures and safety devices (Passenger Emergency Stops, Emergency Brake Mushroom Button, Interior and exterior side door releases).

1. End doors shall be verified to open when the Passenger Emergency Stop is pulled.

2. Correct operation of all brake/propulsion interlocks shall be verified. See T 12.03.03

20.22.34. High Speed Circuit Breaker Test

A. The High Speed Circuit Breaker shall be tripped and reset to ensure functionality. See T 9.04.02

20.22.35. Self Tests

A. All systems self tests shall be run. Any faults or issues shall be verified to display on the VMD. Self tests shall include, at a minimum:

1. Line Filter Capacitance See T 10.04.04
2. The Propulsion System
3. API & LVPS
4. Trainlines
5. ATP/ASR
6. Doors (all controllers)
7. Friction Brake Control Unit
8. Event Recorder
9. HVAC units

20.22.36. API Capacity

A. Each API shall be verified to simultaneously operate all auxiliary subsystems on the car. See T 9.05.03.

B. A failure of one API on a Married Pair shall be simulated to ensure load transfer automatically occurs. See T 9.05.06

1. Loads transferred shall include the air compressor, propulsion inverter cooling fans (if required), floor heat (if applicable) cab heaters and heated windshields.

20.22.37. Power Supply Tests

A. All LVPS, HVAC inverter and aux power inverter loads shall be energized to ensure proper operation and functionality of each sub-system.

B. The dead battery start feature shall be tested. The feature shall power up the car any time the primary power is between 400 and 800 volts. See T 9.06.04

C. With the vehicle powered by the third rail, a meter shall be used to verify that high voltage is not present on the shop power receptacle.

D. With the vehicle powered by the shop power plug, a meter shall be used to verify that voltage is not present on the current collectors.

20.22.38. Battery Tests

A. The battery temperature and charging voltage shall be verified on the LVPS PTU to be within normal range. See T 9.08.01

B. The battery over-temperature protection shall be tested to ensure it properly detects over-temperature. See T 9.08.04

C. 600 from power shall be removed the Married Pair. The following loads shall be maintained for 60 minutes:

1. Side Door Control (1 cycle of operation only)
2. Emergency Interior lighting, which may be dimmed but not below APTA Standard SS-E-013-99 Rev 1.
3. Marker and Tail Lights
4. End Door Vestibule Lights
5. Parking Brake Light
6. Communications:
    a. Train Radio
    b. Passenger Emergency Intercom
    c. Crew Intercom
    d. Public Address
7. Event Recorder
8. CCTV
9. Master Controller
10. Other essential functions as determined during vehicle design and reviewed and accepted by the Authority.

D. After completion of the 60 minutes, the following loads shall remain connected and the equipment shall remain operational for an additional 30 minutes, at a minimum.

    a. Emergency Interior lighting (which includes cab lighting), which may be dimmed but not below APTA Standard, RT-S-VIM-020-08 Table 1.
    b. End Door Vestibule Lights
    c. Marker and Tail Lights
    d. Parking Brake Light
    e. Event Recorder
    f. Master Controller
    g. Communications:
        (1) Train Radio

(2) Passenger Emergency Intercom

(3) Crew Intercom

(4) Public Address

20.22.39. Side Door Operation Test

A. Doors shall be opened and closed from all control devices (trainlines, local cab, crew switches, door pushbuttons):

1. Door close time shall be verified to be in accordance with setpoint determined at design review.

B. The door enable command shall be sent from the local cab door or trainline controls. All interior and exterior door pushbuttons shall show the amber LED illumination and be enabled to open the local doorway.

1. Door pushbutton indicators shall be verified to extinguish when a Close command is sent or the door is locked out of service.

C. All side doors shall be checked for proper operation, including:

1. Forces on door closing, obstruction detection and correct door recycling.

2. All door open indicator lights, audible chimes and car level indicators shall be verified to be in proper operation.

3. Loss of No Motion shall be simulated to ensure doors and bridgeplates are powered closed.

4. Each door panel lock properly cuts out the panel, prevents it from opening and makes the door summary circuit.

20.22.40. Indicator and Chime Tests

A. Door indicator lights and audible chimes shall be checked for correct functionality.

20.22.41. Testing of Side Door Controls in Cab

A. Passenger door controls shall be active in any cab with the Door Setup Switch in the ON position. See T 5.03.07

1. The Door Setup Switches of all cabs in the train-set shall be placed in each position, ON, OFF and THRU, such that all different configurations of the 3 switches are selected.

a. The amber LED indicator light on each door control panel in the train-set will illuminate whenever an incorrect Door Setup Switch position is set.

b. The door control circuit breaker shall be verified to trip after 15 seconds (or other time selected by the Authority), as a result of two cabs attempting to operate the same doors.

c. The VMD shall be verified to indicate which switches are in incompatible positions.

B. The red LED indicator on each Door Control Panel shall be verified to illuminate whenever the car is placed in No-Motion Bypass.

C. The buzzer on each of the door control panels shall be depressed. The buzzer trainline shall be energized and power all buzzers in the train-set.

1. Buzzer pushbuttons shall be operational as long as the Door Setup Switch is placed in the ON position.

2. Buzzer pushbuttons shall be disabled if the switch is positioned in the THRU or OFF position.

D. Headlight Testing

1. Verify that the headlights shall remain ON at all times in the lead cab when the direction switch is in forward position. See T 8.02.03

2. Verify that placing the direction switch in the reverse position shall energize the headlights at the rear end of the train-set.

3. Verify that the marker lights energize whenever the car is keyed up.

4. Verify that the low beam is angled downward in accordance with the results from the qualification test.

20.22.42. Exterior Light Testing

A. Verify that the green, sidewall mounted Parking Brake Light on each side of the car is illuminated whenever the Parking Brake is applied. See T 8.02.04

B. Verify that the amber, sidewall mounted Snow Brake/Sleet Scraper indicator Light on each side of the car is illuminated whenever either of the devices are activated.

C. Verify that the blue, sidewall mounted Propulsion Fault Light on each side of the car is illuminated whenever the propulsion faults.

D. Verify that the amber ATP Bypass indicator light on the front of the car is not illuminated whenever the ATP system is in Bypass mode.

E. Verify that the security light, located and colored in accordance with design review decision by the Authority, is illuminated whenever the security pushbutton is activated.

F. Verify that the red, sidewall mounted Door Summary Indicator Light on each side of the car is illuminated when the door summary circuit is open and flashes when the car's No-Motion Bypass is set to Bypass. See T 6.04.01

G. Verify that the end door light energizes when the end door is opened.

H. Verify that all loop step lights at uncoupled ends are on (at all times).

I. Verify that the passenger interior lighting can be turned on or off from any cab in a train without requiring a transfer switch key. See T 8.04.02

20.22.43. Emergency Lighting Tests (Battery Charging Disabled)

A. Verify that all exterior lights remain powered.

B. Verify that passenger area emergency lighting levels are above the levels required by APTA SS-E-013-99. Rev 1.

C. Ensure that end door vestibule lights illuminate at all times, including when the end door is closed.

D. Verify that all lights in the cab can be energized.

20.22.44. Destination Sign And Interior Message Display Tests

A. Verify that all destination signs, Transverse Announcement Display signs, LCD screens and LED Line maps operate properly.

20.22.45. ATP/ASR Functional and Safety Tests

A. Verify that the system is continuously self-testing by introducing a simulated failure.

B. Verify that the ATP receiver sensitivity is properly adjusted and that the ATP properly decodes all signal aspects.

C. Verify that the ADU displays the vehicle speed and speed code.

   1. Accelerate the vehicle until the train speed violates the limit. Verify that the ADU begins to flash at 1 cycle per second. See T 15.02.07

D. In Manual and Manual release mode, verify that an overspeed condition sounds the audible alarm. See T 15.02.07

E. Activation of the Emergency Bypass Switch shall illuminate an Emergency Bypass indication on the Hostler Panel. See T 15.02.08

F. Verify that the Operations Control Center receives changes in the operation mode.

G. Vital break down tests shall be performed on all external vital ATP circuits.

H. Software installed on each unit shall be verified to be identical to the safety tested software.

I. All vital relays shall be tested and tagged.

J. Perform the Departure Test detailed in T 15.05.01.

20.22.46. Discrete Trainline Tests

A. Verify all remaining cab controls and hostler panels are locked out after a cab or hostler panel is setup for train Control. See T 24.07.06

B. Verify that the Bell and Buzzer Trainlines activate all bells and buzzers in the train. See T 24.07.06

C. For both left and right door control trainlines, ensure that all doors are powered closed when either the Door Open or the Door Unlocked Trainlines are opened. See T 24.07.06

D. Ensure that a Ramp Request (left or right) activate the Ramp Request indication light in the Left Side Door Control Panel of the cab set up for Door Control.

E. Ensure a Ramp Deploy Request (left or right) deploys the ramp from which the request was initiated. Same as Ramp Request Left but for the Right Side.

20.22.47. Event Recorder Tests

A. Verify that the event recorder captures all information as required in T 25.02.03 Event Recorder, Data Recorded, and is accessible via Laptop and USB interface.

20.22.48. Multi-car Trainline Test

A. Verify that all Trainline signals running through automatic couplers (on each end of a Married Pair) are received and reacted to properly by the adjacent Married Pair. Verify all signals sent by the adjacent Married Pair cause the appropriate reaction by the subject Pair.

20.22.49. Car Weighing

A. Load cells shall be used at each wheel to determine the wheel load of the 8 wheels of the completed car. Weight tickets from calibrated load cells shall be included in the Car History Book.

20.23: ON-SITE COMMISSIONING TESTS

20.23.01. On-Site Commissioning Tests on All Vehicles

A. The On-Site Commissioning tests are intended to verify all vehicle functions are operating correctly and have not been impacted by vehicle shipment. For this reason, the Authority preference is for all tests included in T 20.22, Production Testing on All Vehicles, be repeated. The Authority is willing to consider an abridged version of the tests if the Contractor can demonstrate that reduced testing satisfies the intent of full vehicle functionality verification.

20.23.02. Parking Brake Tests

1. The parking brakes shall be engaged on each end of a Married Pair stopped on a grade and service brakes shall be released. Parking Brake shall prevent car movement. See T 12.02.12

2. The parking brake indication lights shall be verified to energize.

3. Power shall be taken after the parking brakes are released. Roll back prevention shall be verified.

20.23.03. Service Brake Rate Tests

A. Tests of the dynamic and friction brake rates shall be performed per the requirements of T 20.20.04, Dynamic and Friction Brake Tests.

1. Tests shall be performed at AW0.

2. Brake rates shall be verified using virtual chart recordings and the Velocity/Time (V/T) method.

20.23.04. Emergency Brake Tests

A. Emergency brakes shall be verified to engage under all the conditions described in T 20.20.05, Emergency Brake Tests.

B. Emergency Brake rates shall be verified to meet the 3.25 mphps +/-20 percent requirement.

1. Tests shall be performed at AW0.

2. Brake rates shall be verified using virtual chart recordings and the V/T method.

20.23.05. Propulsion System Tests

A. The vehicle shall be tested to ensure that the acceleration rates of T 20.20.07, Propulsion System Tests, are met.

1. Tests shall be performed at AW0.

2. Average acceleration rates shall be measured up to the base speed using the V/T method.

20.23.06. ATP/ASR Tests

A. Verify that the ATP/ASR system is operational in all the modes of operation. See T 20.20.10 for information.

B. Verify the overspeed and emergency overspeed protection is enforced per T 20.20.12, Overspeed Limits.

C. Verify the operation of all vital relays listed in T 15, ATP & ASR.

20.23.07. 1000 Mile Operational Test

A. As a final test, cars shall be arranged as 6 car train-sets (3 Married Pairs) and shall pass a 1000 mile (1609 km) pre-revenue service operation test on the Authority's right of way. The vehicles shall be operated by Authority personnel. Equipment shall be cycled on a regular basis to simulate actual in-service conditions.

B. Equipment failures during this test will result in a resetting of the mileage.

C. If operational test results are satisfactory (e.g. no failures), the Authority may entertain a reduction in mileage required for this test. The Authority reserves the right to revert to the 1000 mile requirement at any time, regardless of test results.

20.24: SAFETY

A. Each test procedure shall include safety precautions to protect Contractor and Authority personnel from potential hazards during testing.

20.25: COMPATIBILITY

A. Testing on the Orange and Red Line cars shall be identical, to the maximum extent practical. Test Procedures and results may be shared between the vehicle types if both vehicles' requirements are verified during the test.

B. All requests for test sharing shall be submitted to the Authority for review and approval. Requests shall document the differences between vehicle requirements and the testing intended to prove specification compliance for both vehicles.

20.26: CDRL ITEMS REFERENCED

CDRL 20-01, “Master Test Plan”, (Ref: T 20.02.01A)

CDRL 20-02, “Vehicle Qualification Test Procedures”, (Ref: T 20.02.02A)

CDRL 20-03, “Vehicle Production Test Procedures”, (Ref: T 20.02.03A)

PART T 21.00
MANAGEMENT & PROGRAM CONTROL

Table of Contents

21.01: GENERAL

A. This section includes Project Management, drawings, documents and supporting functions.

B. Separate and individual packages of drawings, documents and data will be provided to the Authority for the Orange and Red Line vehicles.

C. CDRLs shall be submitted individually for the Red and Orange Line vehicles, unless stipulated otherwise.

D. Drawings and documents that apply to both Red and Orange Line vehicles may be submitted once to cover both requirements.

21.02: MANAGEMENT PLAN

A. The Contractor's Management Plan shall be in accordance with the requirements of the contract Section B (Technical Approach, Manufacturing Plan, Quality Assurance Plan) of the Contractor's Proposal. The Contractor's Management Plan shall be submitted to the Authority for review and approval. [CDRL 21-01]

   1. The Contractor shall provide, as part of their Management Plan, an Organizational Chart of key positions for principle sub-contractors. Contact information for these positions shall be provided.

B. The Contractor's Project Manager shall be the prime contact person to the Authority. All subcontractor formal correspondence shall be through the Contractor's Project Manager.

C. Any planned changes of key personnel named in the Project Organizational Chart shall be submitted in advance for approval by the Authority.

D. The Systems Integrator shall be in place as a distinct dedicated position and remain so until the acceptance of all qualification tests and until a minimum of 12 cars of each fleet have been conditionally accepted.

   1. The Contractor's Systems Integration Plan shall be based on the Preliminary Systems Integration Plan submitted as part of the Contractor's proposal.

      a. The Systems Integration Plan shall include the Contractor's processes and procedures for ensuring and validating that system integration is embedded in the vehicle design and manufacturing process.

      b. The Systems Integration Plan shall include, but not be limited to, the interaction between T 12, Friction Brakes and T 10, Propulsion and Dynamic Braking, the testing requirements of T 15 ATP & ASR, T 16, Vehicle Monitoring System, and T 24 Trainlines & Networks. The Systems Integration Plan shall be submitted to the Authority for review and approval. [CDRL 21-02]

2. All drawings and documents of a particular subsystem or component that interfaces in any way with another subsystem or component shall be reviewed and approved by the System Integrator before submittal to the Authority.

3. Any interfaces and/or protocols between two or more systems or components shall be tracked through an Interface Control Document (ICD). Conflict resolution shall be documented in this Document as well. The ICD shall be submitted periodically as agreed upon with the Authority. [CDRL 21-03]

E. The Reliability, Maintainability, Safety and Human Factors Engineer (RMSH) shall be in place until the completion of all reliability testing as specified in T 02.03, Reliability.

21.03: INTERFACE WITH SUBCONTRACTORS, DESIGNERS, SUPPLIERS AND DESIGN-BUILD CONTRACTOR

A. Contractor interface with subcontractors, designers and suppliers will be in accordance with section C5.15, Assigning or Subcontracting.

21.04: INITIAL MEETINGS

A. Within 30 days after NTP a series of Kick-off Meetings shall be conducted to introduce key staff, discuss the document management protocol, establish activities for the following 90 days, and to discuss any other items necessary to establish the overall project management and administration processes.

B. Within 60 days after NTP a detailed specification review shall be conducted to address any outstanding questions that the Contractor may have regarding the technical specification. The goal is that all project participants fully agree on the meaning of the requirements contained within the specification. In addition to the Contractor, all key subsystem suppliers shall participate.

21.05: MONTHLY PROGRESS REPORTS AND SCHEDULE

A. Project meetings will be held in accordance with section C5.16, Project Meetings.

B. Monthly progress reports will be provided five business days before the regularly scheduled Monthly Project Meetings.

C. Monthly Progress Report will be in a format approved by the Authority and shall include, but not be limited to:

1. Current project status summary

2. Project calendar

3. Activities during period

4. Plans for next period

5. Open contractual and technical issues

6. Major problem areas, risks and concerns

7. Weight Report in accordance with T 02.01.07, Weight Management Program

8. Monthly Quality Report in accordance with T 19, Quality Assurance

9. CDRL Submittal Matrix

10. Current Detailed Project Schedule per C4.03, Scheduling

11. Cost tracking

21.06: DESIGN REVIEW

A. Following the detailed specification review (21.04.B) the Design Phase will consist of two formal Design Reviews which shall be conducted for each major system, including the carshell:

   1. Preliminary Design Review (PDR)

   2. Final Design Review (FDR)

B. Interim Design Meetings or Working Sessions may be held as deemed necessary.

C. Subsystem supplier participation is mandatory for the design review meetings.

D. The following table summarizes the aspects of the design that at a minimum will be reviewed:

Element	**Sub-Element**	**PDR**	**FDR**
System Design	Functional Description	X	X
	Supporting Calculations and Analyses		X
	Contractor Specification	X	X
	Outline Drawings	X	X
	Exploded Isometric Drawings		X
	Component Details		X
	Installation Drawings		X
	Installation And Maintenance Clearance Drawings		X
	Bill Of Materials		X
	Interface Analysis	X	X
	Interface Drawings		X
	Subcomponent and Supplier Information	X	X
	Subcomponent Drawings	X	X
	Fire Safety and Toxicity Analysis		X
	Weight Report	X	X
	EMI Susceptibility		X
	EMI Mitigation Plan	X	X

Support	Training Requirements	X	X
	Training Plan and Syllabus		X
	Maintainability Report	X	X
	Maintenance Requirements		X
	Maintenance Documentation Plan	X	
	Maintenance Documentation Drafts		X
	Spare Parts Requirements		X
CDRL	All	X	X
Specification Deviation	Required	X	X
	Recommended	X	
	Commercial, Weight, and Schedule Impact	X	X
Testing	Test Plan	X	
	Test Procedures		X
Value Added	Recommendations	X	

21.07: DESIGN APPROVALS, CONTRACTOR'S DRAWINGS, DOCUMENTATION AND DATA REQUIREMENTS

21.07.01. Review Procedures

A. The following procedure shall govern all submittals for review by the Authority:

1. Documents and Drawings shall be submitted by serialized letter as required in T 21.07.06, Correspondence Control.

2. Two (2) full-size hardcopies of Contractor drawings prepared specifically for this contract shall be supplied to the Authority.

3. Submittals shall simultaneously be submitted electronically through the document management system to the Authority.

4. Electronic submittals shall be provided in Adobe Acrobat PDF format. PDF drawing submittals shall be legible when printed at an 11 X 17 inch size on a b/w printer. Other documents may be submitted at an 8.5 X 11 inch size and shall be in color where appropriate.

5. Two (2) copies of all supplier drawings, catalog cuts, instruction books, renewal parts data lists, tabulations and the like that are not adaptable for the furnishing of reproducibles, shall be supplied. This information shall simultaneously be submitted electronically to the Authority.

B. Review procedures shall be as follows:

1. The Contractor submits drawings and other required documents for review.

2. The Authority shall respond as rapidly as practical (30 working days average time from receipt) to the Contractor, providing adequate review comments where appropriate.

3. The Authority's response shall identify the submitted drawings' or submittal's status as one of the following categories:

    a. Conforms

    b. Conforms as Noted

    c. Revise as Noted and Resubmit

    d. Rejected - Resubmit

    e. Review Not Required

C. The Authority will make every effort to expedite review of submittals to protect the Contractor's required lead time and delivery schedule.

D. Duplicate copies of submittals designated in any of the categories, except "Rejected" or "Review Not Required" shall be signed by the Authority, in a rubber stamped block to be applied by the Authority, with one copy being returned to the Contractor.

E. Drawings designated in categories (b), (c), and (d) above shall be promptly revised and resubmitted by the Contractor.

F. Commencement of vehicle construction without drawing(s) depicting the corresponding work have been submitted to the Authority and have been designated "Conforms" or "Conforms as Noted" will be at the sole risk of the Contractor.

1. It is not the intent of the Authority to require that all detailed drawings be submitted for review before any work can commence, however, for critical structures or connections details shall be provided and supported by underlying design calculations.

2. The Contractor should submit drawings showing physically related areas of the car as simultaneously as possible. When related drawings are not submitted, the drawing database and transmittal cover letter shall reflect the anticipated submittal dates for related drawings or documentation.

3. Authority acceptance of the Contractor's drawings and data shall be for general detail and arrangement only, and shall not relieve the Contractor of any responsibility including, but not limited to:

    a. Full compliance with the Contract requirements

    b. Correctness of dimensions, clearances, and material quantities

    c. Proper design of details

d. Proper fabrication and construction techniques

e. Proper coordination with subcontractors

f. Providing all devices required for safe and satisfactory construction and operation

G. The Contractor shall remain responsible for conformity of its drawings and documents to the Contract documents and specification.

21.07.02. Requirements for Drawings, Documents and Data

A. Individual drawings shall be prepared for each part designed and/or manufactured by or for the Contractor.

B. Any and all drawings, shop drawings, plans and specifications produced by the Contractor shall upon presentation to the Authority, become the property of the Authority consistent with C5.11, Intellectual Property Rights.

C. Assembly, sub-assembly and arrangement drawings shall include a complete Bill of Materials on the field of the drawing or as a subsequent sheet. The Bill of Materials shall describe all items, including the subcontractor's parts and all equipment and details which form part of the assembly.

D. American Welding Society (AWS) standards, references and symbols shall be used at weldments in drawings.

E. All the drawings supplied by the Contractor in accordance with this Specification shall be so delineated that the wiring, piping, or mechanical interference between components shall be readily and clearly identifiable.

F. The Contractor shall submit all design layouts, assembly, and subassembly drawings of safety related features for review by the Contractor's Safety Engineer prior to their release for production to assure the safety of operations personnel, maintenance personnel and the riding public.

G. The Authority will develop and maintain a "Document Management Database". Through the database, the Contractor shall, at an interval established by the Authority, prepare and submit for review:

1. An index of drawings by number, title, revision level and current submittal status

2. A Drawing Tree index by subassembly within the vehicle configuration

3. An index of drawings grouped by system and subsystem

H. Drawing Sizes and Requirements

1. All drawings shall be prepared in American National Standards Institute (ANSI) standard sizes.

2. All drawings shall utilize the Authority's standard title block in the lower right corner, as illustrated in Figure EEQA-AV size Title Block, in the appendix.

3. All drawings shall utilize the Authority's standard application block in the upper right corner, as illustrated in Figure EEQA-AV size Title Block, in the appendix.

4. All drawings shall include at the bottom center a car locator that illustrates the section of the car to which the drawing applies.

5. Contractor shall be responsible for preparation of standard drawing sheets with borders and title and application blocks as described above.

6. The Contractor shall be responsible for the conformity and standardization of all sub-suppliers drawings to be submitted to the Authority.

7. The Contractor's standard drawings (drawings not prepared specifically for this Contract) shall be furnished with the Contractor's title block, and the Authority's block applied in a convenient location in or near the upper right corner on drawings furnished to the Authority as record drawings.

I. Bills of Material

1. All drawings shall include Bills of Material with a numbering system for easy identification on the drawing.

2. Bills of Material shall indicate piece part and assembly weights.

3. Bills of Material shall include US equivalent units.

4. Bills of Material shall be carried on the drawings, or on attached sheets of the same size.

5. Bills of Material descriptions shall positively identify the materials used.

6. For items on the Bills of Material referring to common manufactured materials, the description shall contain the manufacturer name, and manufacturer’s part numbers for the material.

7. The Bill of Material shall have a separate column for future insertion of Authority part numbers.

J. Dimensions

1. All dimensions shall be shown in both English and metric units.

   a. Metric dimensions, enclosed in parentheses, shall follow English dimensions.

2. English units shall be shown consistently on all drawings as follows:

   a. Inches and fractions, or inches and decimals throughout.

b. One inch mark (") shall be shown to the right of each dimension.

c. Decimals shall be shown with maximum of three significant figures to the right of the decimal point as required.

d. Dimensions up to and including 72" shall be shown in inches.

e. Dimensions above 72" shall be shown in feet and inches.

3. Metric units shall be shown consistently on all drawings as follows:

a. Metric units shall be shown as millimeters and decimals.

b. Millimeter units shall be accompanied by one blank space and the letters "mm" to the right of the figures.

c. Dimensions smaller than one meter shall be shown in millimeters.

d. Dimensions one meter and larger shall be shown in meters and decimal meters (1.000 m)

e. Decimal units shall be shown with as many significant figures to the right of the decimal point as required.

K. Stationing

1. Numerical station dimensions and lines shall be used on all assembly drawings, and as frequently as possible on detail drawings and views, to locate the individual items in the overall car configuration. All assembly and sub-assembly drawings shall contain station information to accurately locate the item on the car.

2. Stations shall be shown in three planes:

a. Longitudinally, commencing with the pulling face of coupler (P.F.C.) at the front end of the car.

b. Transversely, commencing with the longitudinal centerline of the car and increasing left and right.

c. Vertically, commencing with the tops of the running rails.

d. Station figures shall be enclosed in circles.

e. Transverse dimensions shall have the letters "L" or "R" shown below the figures, to indicate "left" and "right".

f. Vertical dimensions shall have the letters "ATOR" (above top of rail) shown below the figures.

L. Numbering

1. The Contractor shall confer with the Authority in order to develop a numbering system compatible with both the Contractor and Authority's standard numbering systems.

2. All revisions of drawings shall be identified with an alphabetic suffix.

3. Orange Line and Red Line drawings shall have distinct and separate numbering systems. However, where part or subsystem commonality has been achieved between the Orange and Red Line vehicles, it shall be noted on all relevant drawings and documents. Commonality shall also be recorded on the Drawing Database. All parts that are common between the Red and Orange Lines shall share the same part number.

M. Schematics

1. The Contractor shall prepare and submit, for acceptance by the Authority, an integrated schematic diagram package relating all electrical systems and including all components and all wiring on the cars.

2. The schematic diagram shall be one which can be readily followed by technicians with basic electrical knowledge.

3. Both an alphabetic tabulation and pictorial locator of all electrical components and devices and the physical location of these components shall be included with the integrated schematics. This tabulation should also identify the circuits where components are used, and the location of each circuit in the schematic package. Each drawing within the schematics shall include a grid locating system which shall be referenced for continuation to other drawings.

4. The Draft Schematic Format shall be submitted to the Authority for review and approval. [CDRL 21-04]

5. In addition to electrical schematics, the integrated schematic package shall contain pneumatic schematics including, at a minimum:

   a. Compressed Air System, Brake System, secondary suspension and any other pneumatic components or systems.

6. The schematics shall be accompanied by a complete Wire List. The list shall include for each wire, as a minimum:

   a. Originating equipment

   b. Destination equipment

   c. Wire size and type

   d. Conduits and Raceways through which the wire runs

   e. Wire number

7. This list shall be provided in an electronic database format (with database software and license provided). The database shall be arranged in logical fields that will allow various sorts of the information (such as by equipment, wire number, conduit, etc.). Both hardcopy and electronic media file shall be provided.

N. Complete wiring diagrams shall also be provided for all car wiring. These diagrams shall be arranged logically and all text shall be clearly legible. Diagrams shall identify all conduits and raceways in which wires are run, identify all wires in each conduit/raceway, and shall clearly denote all connections at terminal blocks and connectors.

O. A separate drawing noting the physical locations of all terminal boards and junction boxes shall be provided as part of the wiring diagram package

P. The schematics shall be provided in B size, 11 inch by 17 inch packages. All schematics shall be prepared so that all text and other items on the drawings are clearly legible on the 11 inch by 17 inch sheets. Refer to T 22.02.03, Running Maintenance Manual, for further details.

Q. Samples of the schematic, electrical component/device table, wiring diagram, and wire run list shall be submitted to the Authority for review and approval before submittal as a component of the maintenance manuals. [CDRL 21-05] Hand-drawn drawings shall not be permitted.

R. In addition to electrical schematics, the Integrated Schematic shall also provide physical of the electrical system components.

S. The Integrated Schematics shall include all electronic and electrical components on the car. All minor subsystem components housed in “black boxes” shall also be included in the Record Drawings Schematic Package. For the Integrated Schematic Package such components shall be treated as black boxes. Refer T 22.02.03, Running Maintenance Manual, for further details.

T. The Integrated Schematic Package shall be comprised of two parts:

1. Integrated Schematics per T 22.02.03.G

2. Integrated Wiring Diagrams per T 22.02.03.J

U. The Integrated Schematic Package shall be submitted as a component of the Running Maintenance Manuals in accordance with T 22, Systems Assurance.

V. All other document control and formatting requirements shall be discussed and agreed upon within 30 days after the project kick-off meeting.

21.07.03. Drawings and Documents Requiring Approval

A. The Contractor shall submit to the Authority and to the Consulting Engineer, in accordance with the schedule, Part C5.02.A.2, all design and engineering information including but not limited to:

1. Contractor’s Specification
2. General Arrangement Drawings
3. Carbody Structural Drawings
4. Truck Structural Drawings
5. Plan Layout Drawings
6. Section Drawings
7. Static and Dynamic Clearance Diagrams
8. Cab and Console Arrangement Drawing
9. Schematics (electrical and pneumatic)
10. Wire List
11. Printed Circuit Board Drawings
12. Styling and Painting Drawings
13. Installation Drawings
14. Assembly Drawings
15. Component Drawings
16. Component Data Sheets
17. Vendor Drawings
18. System Functional Descriptions
19. Interface Control Document
20. System and Subsystem Performance and supporting information
21. Reliability, Maintainability, and Safety Data and Analyses
22. Software Documentation
23. Test Plans
24. Action Items and Mitigation Plans, where appropriate
25. EMC Control Plan
26. Configuration Management

27. Recommended Spare Parts Lists

28. Lists of Special Tools and Test Equipment

29. Other general information required for the understanding, operation, and maintenance of the vehicles.

21.07.04. Documents Requiring Approval

A. The specification contains Contract Deliverable Requirements List (CDRL) items. Each document labeled CDRL shall be submitted for review and approval by the Authority.

B. CDRLs shall be delivered in accordance with their due dates and the Authority approved Submission Schedule described in C 5.02 and T 21.09 below.

C. The due dates shown in the CDRL are anticipated submission dates and will be compared to the Contractor's proposal. Potential changes will be discussed and agreed upon.

21.07.05. Construction Photographs

A. The Contractor shall take photographs showing the progress of the cars during construction.

B. Each photograph shall show a different view of the work, and shall be made at times and from vantage points designated by the Authority.

C. Additional photographs shall also be taken of major components, such as the carshell, trucks, electrical cabinets, Operator's console, etc. during the assembly of the car.

D. The minimum of 500 photographs shall be taken during construction of each fleet (Orange Line, Red Line).

E. The Contractor shall submit photographs digitally in JPEG format.

   1. Alternative formats may be proposed for acceptance by the Authority.

F. The digital pictures shall be accompanied by an index cross-referencing the file name to all relevant information including the vehicle number, date taken, descriptive data, and the names of the Authority and the Contractor.

G. During the hours which the production facility is open and operating, the Authority's authorized representatives shall have the right to take additional photographs of the work with the Authority's equipment and at the Authority's expense.

H. At the completion of the first vehicles for both the Orange and Red Line, photographs will be provided in accordance with section C5.17, Project Photographs.

21.07.06. Correspondence Control

A. All correspondence will be made in accordance with section C5.18, Further Obligations.

B. Correspondence will be serialized in accordance with Authority approved methods. Serialization will include at a minimum:

1. Correspondence number

2. Date

3. Reply by

4. In Reference To (if applicable)

5. Specification Reference (if applicable)

6. Action Item (if applicable)

C. All correspondence shall be provided in Adobe Acrobat PDF format. Certain documents may be required by the Authority in MS Office format to simplify further processing.

21.08: CHANGES

21.08.01. Approvals of Alternate Design or Components

A. This performance specification contains few detailed requirements where alternate proposals can be made to the Authority for approval. The Contractor shall submit all supporting information that prove that the alternate proposal is equal to or better than the existing requirements, and provide a detailed explanation why a change is desired or required, in a Specification Approval Request (SAR).

B. The Authority will review and evaluate the SAR and either reject it, request additional information, or accept it. If deemed necessary, the technical specification may be revised, using a formal Specification Change Notification (SCN) that will be signed by both parties.

21.08.02. Design Changes after Pilot Train delivery

A. If during or after Pilot Train testing and commissioning design changes, including software, are deemed necessary, the Contractor shall formally submit such change for approval through an Engineering Change Notification (ECN). All supporting information shall be provided, including reason for change, updated drawings and other documentation, modification plan and schedule, impacted production vehicles, detailed Field Modification Instructions (FMI) as appropriate, parts required, and any other data required to allow the Authority to fully evaluate the request.

B. In the Warranty Plan defined further under C4.02.B, the Contractor shall include sample ECN and FMI forms. [CDRL 21-10]

21.09: INITIAL DRAWINGS, DOCUMENTS, AND DATA TO BE FURNISHED BY CONTRACTOR

A. In accordance with C5.02, the Contractor shall submit a proposed Submission Schedule to the Authority for review and approval, within one month from Notice-To-Proceed. [CDRL 21-06]

21.10: FINAL SUBMITTALS TO BE FURNISHED BY CONTRACTOR

21.10.01. Drawings

A. The drawings shall be submitted for final record, after review by the Authority, in accordance with the schedule and prior to completion of the contract. [CDRL 21-07]

B. The Contractor shall provide updates to the Final Drawings to incorporate any and all approved field modifications.

21.10.02. Electronic Format Submittals

1. All drawings, including the integrated schematic, shall also be submitted in electronic format on CD-ROMs, capable of being copied.

2. Drawings shall be in AutoCad format.

   a. Alternate editable drawing formats may be proposed for review and acceptance by the Authority.

   b. An additional copy of the drawing shall be provided in Adobe Acrobat PDF format.

3. Coincident with the submittal of the electronic drawings, the Contractor shall provide two copies of the current version of AutoCad or alternate software to facilitate the display, review, mark-up, edit and printing of the electronic drawings. The software shall be capable of running under the latest Microsoft Windows operating system.

21.10.03. Contractor's Specification and Record Drawings (As-Builts)

A. Final Record Drawings and Contractor's Specification shall incorporate all engineering, manufacturing, and installation changes made through the delivery of the last car.

1. The Contractor Specifications shall generally follow the Authority’s procurement specification, listing all design criteria and parameters; the manufacturer and model number of all major equipment; and inspections and test procedures.

2. Provisions shall be incorporated for Change Orders and, if applicable, approved deviations from the specification.

3. The Contractor shall submit revisions or addenda as required for any modifications or retrofits performed during the warranty.

B. The Contractor's Specification is the final As-Built specification.

1. Contractor shall submit 4 draft copies of the Contractor's Specification for preliminary acceptance, with the design and engineering drawings.

2. The Contractor shall provide 25 copies of the Contractor's Specification after Authority review and approval.

21.10.04. Additional Submittals

A. The Contractor shall furnish to the Authority, at any time requested to do so prior to the delivery of the reproducible drawings, prints of each working drawing for the purpose of maintaining and servicing the cars.

B. The Contractor's attention is directed to Section T 22, Systems Assurance, for details regarding the requirements for Operating Manuals, Maintenance Manuals and Integrated Parts Catalog (IPC).

C. The Contractor shall provide 10 bound copies of a Drawings Cross Reference List by drawing number and title.

D. Not used.

E. 100 copies for each fleet (Orange Line, Red Line) of all catalog cuts, Manuals, renewal parts data (full detail, plus recommended list), lists, tabulations and the like, not adaptable for the furnishing of reproducible items.

21.11: CAR HISTORY BOOKS

21.11.01. General

A. A Car History Book shall be provided for each car in both hard copy and electronic format (PDF). The hard copy shall consist of signed original documents and certifications. Format shall be submitted to the Authority for review and approval. [CDRL 21-08]

B. The Car History Book shall be available upon the Authority's request for review and delivered upon conditional acceptance of the car.

C. The Contractor shall provide updates as required through the warranty period to document any changes made to the car.

D. The Car History Book shall contain, but not be limited to the following information:

1. Car Numbers

2. Table of Contents

3. Certified Weights

4. Serial numbers of all serialized components and assemblies including revision level

5. Air Reservoir Certificates

6. Weight of major components as required by the Weight Program. Refer to T 02, Vehicle Design Requirements, for further details and requirements.

7. Truck data including:

    a. Weight

    b. Axle, wheels, journal bearings and gear box mounting records including pressing charts, manufacturing records and certifications.

8. All Inspection Records including a list of defects noted and the disposition of each

9. Production Test Reports

10. Non Conformance Reports

11. Modifications completed with revision numbers and dates

12. Open Items

13. Software revision levels

14. Hardware revision levels

15. Shipping Documents

21.12: MODIFICATION AND CONFIGURATION CONTROL

21.12.01. General

A. All major components, assemblies, motors, pc boards, components that require repair or rebuild, components specifically called out in this specification and items usually serialized shall be receive unique serial numbers within the component type.

B. The Contractor shall submit, for Authority review and approval, a Configuration Plan. [CDRL 21-09] The Configuration Plan shall include at a minimum:

1. A list of items to be serialized

2. Serialization methodology

3. Configuration records, including:

    a. Hardware revision control

    b. Software revision control

4. Engineering change documentation control, including:

    a. Drawings

    b. Manuals

    c. Part Catalogs

C. Modifications (Change Orders) will be completed in accordance with section C11.

D. The Contractor shall update, submit, and maintain revised drawings.

E. As-Built drawings and Contractor's specification shall have all engineering, manufacturing and installation changes incorporated.

21.13: CDRL ITEMS

CDRL 21-01, “Contractors Management Plan”, (Ref: T 21.02.A)

CDRL 21-02, “Contractors Systems Integration Plan”, (Ref: T 21.02.D.1)

CDRL 21-03, “Interface Control Document”, (Ref: T 21.02.D.3)

CDRL 21-04, “Draft Schematic Format”, (Ref: T 21.07.02.M)

CDRL 21-05, “Documentation and Drawing Samples”, (Ref: T 21.07.02.Q)

CDRL 21-06, “Contractors Submission Schedule”, (Ref: T 21.09.A)

CDRL 21-07, "Final Drawings and Contractor's Specification", (Ref: T 21.10.1.A)

CDRL 21-08, “Car History Book”, (Ref: T 21.11.01.A)

CDRL 21-09, "Configuration Plan", (Ref: T 21.12.01.B)

CDRL 21-10, “Warranty Plan”, (Ref: T 21.08.02.B)

21.14: REFERENCES

21.14.01. Technical Specification Cross References

T 02, Vehicle Design Requirements
T 15, ATP & ASR
T 16, Vehicle Monitoring System
T 19, Quality Assurance
T 22, Systems Assurance
T 24, Trainlines & Networks

PART T 22.00
SYSTEMS ASSURANCE

Table of Contents

22.01: SYSTEMS ASSURANCE REQUIREMENTS

22.01.01. General

A. The systems assurance section of this technical specification defines the in-service support requirements that include materials, equipment and training needed to operate, inspect, maintain, and test the vehicles being provided.

22.02: MANUALS AND CATALOGS

22.02.01. Manual Design - General Requirements

A. The format and content of each manual, parts catalog and/or schematic shall be approved by the Authority.

B. The Contractor shall submit, for Authority approval, a single responsible person, designated as the Manuals and Catalog Manager (MCM). The MCM shall be responsible for the coordination, timely completion, and timely submittal of the Manuals and Catalogs. The MCM shall also be responsible for effective incorporation of the Authority's comments, internal reviews/checks and for the overall quality of the Manuals, Parts Catalogs and Schematics required by this project.

C. The Authority is currently considering an interactive fleet management program. The Contractor shall submit electronic files of all manuals and the Interactive Parts Catalog in a format capable of being imported into the future program.

D. The Manuals and Catalogs shall include a Table of Contents and index tabs for each section. The level sought is embodied in the Air Transportation Association of America's Specification No. 2200 (ATA iSpec 2200), Information Standards for Aviation Maintenance, which shall be used as a general guide. Variations in type face and minor font details may be approved upon request.

E. The Contractor is responsible for providing revisions and updates in a timely manner to any portion of the submitted products due to errors, omissions or modifications to the vehicle and/or systems after the final copies have been delivered.

F. The Contractor shall perform documented reviews and quality checks of each of the products, and their revisions, prior to submitting to the Authority for review and approval.

G. The Manuals and Parts Catalogs shall be complete, thoroughly organized and limited to the information necessary to complete the stated task. Photos, illustrations, cutaway isometric and exploded views shall be included to adequately describe and demonstrate the task, component, system or tests. Step by step assembly and disassembly photos and illustrations shall be included as necessary to accomplish the stated maintenance task.

H. The completed Manuals, and Catalogs shall also be submitted on CD-ROMs or DVD ROMs in HTML format. All photos, images and graphics shall be a scanned image in *.TIF format.

1. The digital versions of the Manuals shall incorporate references to other sections or manuals or catalogs as hyperlinks to the text, image or drawing referenced.

I. The Maintenance Manuals shall contain complete work flow processes as defined below.

1. Corrective maintenance procedures shall be traceable to one or more of the fault isolation tasks identified in the troubleshooting tables. Each fault shall refer the user to detailed tasks which are contained in the maintenance manuals or in another supplied document. References to procedures that are contained in the maintenance manuals shall include the appropriate volume, chapter, and section number. References to other supplied documents shall contain only the document number and title.

   a. Each preventive and corrective maintenance task shall identify the required tools, support equipment, consumables and spare parts. When applicable, repair kits shall be identified. Each procedure shall also refer the user to appropriate figures in the Parts Catalog. Each preventative maintenance task shall identify the applicable kit.

   b. The contractor shall demonstrate that all tasks are complete and traceable throughout the supplied documentation and that the work flow process can be easily followed. This includes ensuring that consistent terminology and nomenclature are used throughout the process. Manuals that contain incomplete work flow processes will be rejected by the Authority.

2. Manual and catalog format shall be as described below.

   a. Except as noted below, all the manuals and catalogs shall be in loose leaf format. Adequate cross-reference and Table of Contents shall be provided for each book. One copy of a final version of all Manuals and Catalogs shall be of high-quality, reproducible format, printed on one side with no hole punches.

   b. Maintenance and Vendor manuals and Parts Catalogs shall be 8 ½ X 11 inch type. They shall be bound along the 11 inch dimension.

   c. Operator's Manual and the Operating Troubleshooting Guide shall be 4 ¼ inches wide, 7 inches high, and not more than 1 ¼ inch thick. They shall be twin loop wire bound along the 4 ¼ inch dimension. The pages shall be coated glossy paper that is waterproof and resists oils, tearing and fading.

3. The publications shall be designed for continuous, long-term service.

4. Cross-references and Table of Contents shall be provided in each book.

5. The format of all data contained in each section of the Manuals and Catalogs shall be consistent from section to section.

6. All Manuals and Catalogs may be submitted in multiple volumes, however, in no case shall systems be split between volumes.

7. All covers shall be approximately 1/16 inches thick, resistant to oil, moisture, and wear, to a high degree commensurate with their intended uses and subject to Authority approval.

8. Diagrams and illustrations shall be line drawings and shall not be loose or in pockets. Diagrams and drawings shall not be more than ½ page fold out.

9. All material shall be clearly reproducible by dry copying machines, which precludes the use of halftone illustrations or photographs.

22.02.02. Operator's Manual (OM)

A. The OM shall contain all information required for optimum operation of the vehicle. It shall include, as a minimum:

1. General vehicle familiarization

2. Location, function and operation of all controls, gauges, indicators, switches and cut outs

3. Emergency procedures

4. Troubleshooting guide

5. Undercar component chart

6. Brief descriptions of the trucks, couplers, lights, HVAC, cut outs, key circuit breakers and other vehicle information required by the train crew.

7. A separately bound Appendix titled, "Operating Troubleshooting Guide" shall be provided for each Line.

   a. This guide shall be identical, in style and format, to the Authority's Blue Line OCC Troubleshooting Guide that will be provided to the Contractor for reference.

22.02.03. Running Maintenance Manual (RMM)

A. The RMM will be comprised of all information necessary for inspection, servicing, troubleshooting and running maintenance activities.

B. Inspection and servicing tasks shall be broken down into elements that are in accordance with the Authority's standard inspection and service intervals. Each inspection task shall include pass/fail criteria and illustrations wherever practical. Should a component or system manufacturer recommend an interval not consistent with the Authority's practice, the Contractor shall submit that interval to the Authority for approval.

C. Running Maintenance shall be comprised of all repair, adjustment and/or component replacement tasks where the repair time and/or replacement unit exchange time is 4 hours or less. It shall also contain recommended cleaning procedures for all lining materials as well as a list of recommended cleaning solutions. The Contractor shall make every reasonable attempt to utilize the cleaning solutions currently used by the Authority.

D. The RMM shall be organized by major system and then subsystem. Each system section shall include:

1. Functional block diagrams with interconnecting signals
2. Theory of operation of the system and subsystems
3. Complete electrical and pneumatic schematics for each system and subsystem
4. A trouble shooting flow chart diagram
5. Instructions for inspection procedures, adjustments, cleaning and replacement of parts and assemblies
6. Time tables for inspection, cleaning, adjustment and replacement tasks

E. The RMM Theory of Operation Sections shall provide an overview of the operation of the system, the function of each signal and a comprehensive, point-by-point, written narrative description of all electrical, electronic, and pneumatic control system operations. The narratives shall reference the schematics. The schematic descriptions shall use flow as a basis for the explanation. The descriptions shall include origin, function, range of values, nominal value, and destination for all input and output signals. Device symbols, wire and pipe designators shall be consistent with those already in use at the Authority.

1. The description of microprocessor controls shall include sufficient information to allow an Authority technician to understand the relationship between processor system inputs and outputs and their relationship to other signals on the cars. The technician must be able to observe processor system inputs and determine if the correct output signals are being generated by the processor based system.

F. The schematic diagrams in each system and subsystem section shall, use identical formats, device symbols, wire and pipe designators. All interfaces, from page-to-page and subsystem-to-subsystem, shall be clearly delineated. Alphanumeric zone locations shall be included for devices and wires when referencing from page-to-page and from volume-to-volume.

1. Top level schematics shall tie together subsystem schematics and supply any connections at the car level.

    a. Where a system or subsystem is trainline or network controlled, a trainline or network schematic diagram for the system or subsystem shall be provided.

2. The electrical and pneumatic schematics shall be sufficiently detailed to permit

Authority electronic technicians to troubleshoot and repair printed circuit boards, as well as shop repairers to troubleshoot and repair car systems. Each component of the PC boards must be individually shown, identified, and described in the schematics, with the actual values for all passive components.

3. Circuit identification shall include, but not be limited to, waveforms, voltages, currents, and pressures for the electrical, electronic and pneumatic circuits. Test points shall be identified and acceptable measurements described.

G. Integrated Schematics shall be provided in a separate double loop, wire bound, laminated volume of the RMM. This volume shall include:

1. An index of drawings, an introduction, an abbreviation list, a device list, and a symbol list.

2. A layout of the cab and non-cab cars showing the physical location of all system modules, junction boxes, network switches and terminal boards.

3. A functional block diagram of each system and interconnections between systems where necessary.

4. Trainline schematics clearly showing the following:

   a. Logic function

   b. Terminal board terminals

   c. Relay contacts

   d. Wire numbers

   e. Cable connector pins

   f. Coupler pins

5. Power and control schematics for all systems to the module level, including all test points.

6. Network diagrams showing switches, gateways, port or cable identification, cable connector pins, and coupler pins used.

7. Pneumatic schematics for the compressed air system, the brake system, the secondary suspension, and any other pneumatic system.

H. Alphanumeric zone locations shall be included for devices and wires when referencing from page-to-page and from volume-to-volume.

I. Each schematic drawing shall identify the numeric value of all resistors, inductors and capacitors included.

J. Integrated Wiring Diagrams shall be provided in a separate double loop, wire bound, laminated 11x17 volume of the RMM. This volume shall include:

1. An index, introduction, abbreviation list, device list and symbol descriptions.

2. A layout of the cab and non-cab cars showing the physical location of all system modules, junction boxes, network switches and terminal boards.

3. Trainline connection diagrams that are based on the integrated schematics.

4. All wiring, cables, conduits, raceways, terminal boards, connectors, junction boxes and equipment cases used for all systems and networks on the cab and non-cab cars.

    a. The wire number and wire size shall be shown for each wire.

22.02.04. Heavy Maintenance Manual (HMM)

A. The Contractor shall provide a list of items that shall be included in the HMM.

B. The HMM shall be comprised of all information necessary for medium to heavy repairs, major component replacement and other maintenance activities.

C. The HMM shall be a fully integrated manual provided by the Contractor. Terminology shall be uniform between manuals. All subsystem manuals shall be included. Where subsystem vendor manuals use different terms or symbols, a translation table shall be provided.

D. Where Test Equipment is required for heavy maintenance tasks references shall be made to the Test Equipment Manuals. Electronic copies of the HMM shall have links to the Test Equipment Manuals for the Test Equipment referenced.

E. Heavy maintenance shall be comprised of all medium to heavy repairs and component replacement tasks where the repair time and/or replacement unit exchange time is greater than four hours.

F. The HMM shall be divided into two major sections, one shall be organized by major system and then subsystem, and the second shall be by time interval including the system/subsystem and the activity to be performed (inspection, adjustment, replacement, etc).

22.02.05. Maintenance Planning Manual (MPM)

A. The MPM shall contain all the information necessary to allow the Authority to plan, schedule and budget all maintenance activities required as detailed in the RMM and the HMM.

B. The MPM shall provide a breakdown of each task required, by system, task type (replacement, inspection, cleaning, etc), interval period, man-hours to complete the task, and required parts list, for all maintenance, inspection and service activities up to the mid-life of the vehicle. The required parts list shall include part description, manufacturer’s part number, quantity, and list prices at the time of production. Draft

MPM shall be submitted to the Authority for review and approval 240 days prior to delivery of the first Pilot Cars. The Final MPM shall be submitted with the parts cost prices based on the most current available prices at the time of final acceptance of the fleet.

C. The MPM shall be broken out into two parts, one sorted by system and the other sorted by service interval, both with all the information required in the preceding paragraph.

D. Overhaul maintenance intervals for components of major subsystems such as trucks or air supply systems shall be coordinated.

22.02.06. Test Equipment Manuals and Schematics

A. The Contractor shall provide a Test Equipment Manual for each type of Test Equipment specified in this section.

B. The contractor shall provide manuals for the use of and troubleshooting of all Portable Test Units (PTU), Diagnostic Test Equipment (DTE), Bench Test Equipment (BTE) and Power Bench Test Equipment (PBTE).

C. The contractor shall provide complete schematic diagrams of all DTE, BTE, PBTE and Automated Test Stands including all custom test fixtures and auxiliary power supplies, etc. needed to test each Line Replaceable Unit (LRU) or Printed Circuit Board (PCB).

22.02.07. Illustrated Parts Catalog

A. The Illustrated Parts Catalog sections shall provide maintenance and stores personnel with the information needed to identify and requisition all replaceable assemblies, subassemblies, components and parts used on the car.

B. The Parts Catalog shall list and describe every item of each system:

1. Figure and Index Number
2. Builder and Subcontractor Part Numbers
3. Part Description
4. Commercial equivalent, where available
5. Quantity
6. System Code
7. Authority Reference Number (to be provided by the Authority).

C. The parts listing shall be designed to show each part's relationship to the next higher assembly. The listing shall also include a reference to the Figures in which full, cut-away and exploded drawings shall show all parts. Systems and components shall be shown in “Top Down” order.

D. The Parts Catalog shall include General and System Tables of Contents. Each table shall include two separate listings: numerical by figure index number and alphabetical by name of part.

E. The Parts Catalog shall contain:

1. Cover Page
2. Table of Contents
3. List of Illustrations
4. Introduction
5. How to Use Catalog Description
6. List of Abbreviations
7. List of names and addresses of all vendors and manufacturers supplying the parts listed
8. Parts List
    a. Alphabetical listing by part, description and illustration diagram
    b. Numerical listing by Manufacturer’s Part Number
    c. An index cross correlating part description, illustration diagram, manufacturer’s part number to Authority part number
9. Illustrations and Exploded View Diagrams

F. The electronic copy of the Illustrated Parts Catalog shall be organized in a manner that allows the interactive part catalog system to provide drill down capability from the assembly to any individual item.

G. The Contractor shall provide updates to the Final Versions of the Maintenance and Parts Manuals to incorporate any and all approved field modifications.

22.02.08. Training Simulator (OPTION)

A. The training simulator shall be a fully interactive operator training program using Computer Generated Imagery (GCI) to model the operating cab controls and track arrangements including reverse and single track operation..

B. The simulator shall present training opportunities with respect to basic skill development, acceleration, braking, and situational awareness decision-making skills and judgment.

C. The simulated environment shall include various track, speed signal aspects, stations, and varying weather conditions representative of the MBTA Red and Orange Lines.

D. The simulator shall include two (2) complete, fully interactive student training stations and one instructor station to oversee and control the training process.

E. The instructor station shall be capable of supporting either a standalone training session or multi-participant (network) training exercises. The instructor station shall allow direct interaction between the instructor and trainee(s).

F. The Contractor shall submit a detailed functional description of the training simulator [CDRL 22-01]

22.02.09. Delivery Schedule for Manuals

A. Drafts and Final versions of the Manuals, Parts Catalogs and Schematics shall be submitted to the Authority for review and approval in accordance with Table 22-1.

Manual or Catalog	**Due Date**	**Quantity (Note 1)**	**CDRL**
Operator's Manual			
Sample	90 Days after NTP	1	22-02
Draft	30 Days before Pilot Car delivery	10	22-03
Interim Version	With delivery of the 4th Married Pair for each line	100 Orange 150 Red	22-04
Final	With delivery of last car for each line	300 Orange 500 Red	22-05
Running Maintenance Manual			
Sample	90 Days after NTP	1	22-06
Outline	Vehicle Final Design Review	1	22-07
First Drafts for Each Subsystem	At First Article of Inspection for the subsystem	5	n/a
Draft	6 weeks before delivery of the Pilot Cars	20 Orange 20 Red	22-08
Interim	With delivery of the 20th car for each line	30 Orange 60 Red	22-09
Final	8 months after delivery of the last car for each line	75 Orange 125 Red	22-10
Heavy Maintenance Manual			
Sample	90 days after NTP	1	22-11
First Draft for Each Subsystem	At First Article of Inspection for the subsystem	5	n/a
Draft	With Delivery of Pilot Cars for each line	10 Orange 10 Red	22-12

Manual or Catalog	Due Date	Quantity (Note 1)	CDRL
Interim	12 months after date of acceptance of the first car	20 Orange 20 Red	22-13
Final	8 months after delivery of the last car	50 Orange 50 Red	22-14
Maintenance Planning Manual			
Sample	90 days after NTP.	1	22-15
First Draft for Each Subsystem	At First Article of Inspection for the subsystem	5	n/a
Draft	With delivery of Pilot cars for each line	10 Orange 10 Red	22-16
Final	With the acceptance of the last car for each line	20 Orange 20 Red	22-17
Test Equipment Manual			
Sample	90 days after NTP	1	22-18
First Draft for Each Subsystem	At First Article of Inspection for the subsystem	5	n/a
Draft	With delivery of Pilot Cars for each line.	20 Orange 20 Red	22-19
Final	With Delivery of the last car for each line.	60 Orange 60 Red	22-20
Illustrated Parts Catalog			
Sample	90 Days after NTP	4	22-21
First Draft for Each Subsystem	At First Article of Inspection for the subsystem	5	n/a
Draft	6 Weeks prior to the delivery of the Pilot Cars	10 Orange 10 Red	22-22
Interim	With delivery of the 20th car for each line	10 Orange 10 Red	22-23
Final	With the delivery of the last car for each line	50 Orange 50 Red	22-24

Table 22-1 Manual Delivery Schedule

B. In addition to the number of hard copies of the manuals listed in Table 22-1, 4 CD or DVD copies of all versions of each manual shall be delivered to the Authority concurrent with the hard copy delivery. Electronic copies shall be in HTML format. Adobe PDF format may be provided on the condition that the hyperlink requirements are fully met. In addition, 4 CD or DVD copies of each version of the Illustrated Parts Catalog shall be submitted to the Authority in a format that is capable of being imported into the interactive fleet management program. The electronic copies of all manuals shall be considered part of the referenced CDRLs.

22.03: NOT USED

22.04: DIAGNOSTIC TEST EQUIPMENT

22.04.01. General Requirements

A. The Contractor shall furnish for each car system, test equipment required to perform all testing that is necessary to verify proper operation of and diagnosis of failures of all car systems. This test equipment shall be designed to efficiently isolate defects to the lowest replaceable component level. The test equipment shall require minimal setup and test time.

B. The detailed functions of all test equipment shall be presented during the associated system's design review. The capabilities and functions of all test equipment shall be as approved by the Authority.

C. If at any time during the project, including the warranty period, it is determined that the test equipment does not properly log or isolate faults, or fails to perform any of its intended functions, the Contractor shall reprogram or modify the equipment as necessary.

D. The Contractor shall make any and all modifications to the test equipment defined by this specification which are required because of changes and modifications made to the vehicle or any of its sub-systems.

22.04.02. Test Equipment Deliverables

A. The Contractor shall supply:

1. 20 laptop Portable Test Units (PTUs) for the Red Line, 30 PTUs for the Orange Line, and 10 PTUs for engineering staff.

2. 4 Portable Diagnostic Test Equipment units (DTE) for each Orange Line subsystem requiring such diagnostic equipment and 4 DTEs for each Red Line subsystem requiring such diagnostic equipment.

3. 2 Bench Test Equipment (BTE) systems with interface adapters and cables for each of the following subsystems:

    a. Door Controllers

    b. HVAC System

    c. Auxiliary Power Inverter and Low Voltage Power Supply controllers

    d. Propulsion Logic and control

    e. Friction Brakes Control Unit

    f. Vehicle Monitoring Unit

g. ATP/ASR

h. Communicatioin and Passenger Information Equipment

i. Repairable DC to DC Power Supplies

j. Miscellaneous repairable boards

k. Repairable network equipment

4. A spare set of bench test interface adapters and cables for each board and each Line Replaceable Unit (LRU) shall be provided.

5. 1 Power Electronic Bench Test Unit for testing high voltage power electronics.

6. 2 Automated mechanical test stands shall be provided for brake valves, tread brake units, door operators and air compressors.

7. 3 Automated mechanical test stands shall be provided for testing the HVAC system.

8. 8 Laser printers of the latest generation for printing test reports.

22.04.03. Portable Test Unit (PTU)

A. The PTU shall consist of a ruggedized portable laptop computer with the latest version of Windows™ or other approved operating system. Each PTU shall have the software and hardware to access all intelligent microprocessor based subsystems over the Married Pair Ethernet Diagnostic Network (MPEDN) or directly from the subsystem's local Ethernet port.

1. The PTU shall meet MIL STD 810G for drop resistance, shock, vibration, dust, dirt, liquid, temperature and humidity.

2. The PTU shall have a solid state drive instead of a mechanical hard drive.

3. The PTU shall have at least 2 RJ45 (8P8C) 10/100 Ethernet ports, 3 USB 2.0 (or higher) ports, and one 802.11 wireless link.

B. Access to all subsystems shall be from a main screen and shall be icon driven. Subsystem functions shall be from menus resident within the PTU software and shall interact with the subsystem's on-board control microprocessor.

C. Each PTU shall have the capability to download and display faults and to configure, download and display snapshots in accordance with T 16.07, Fault Management Description.

D. Each PTU shall have the capability of running the diagnostic software for each subsystem as well as displaying the results. Help screens shall be available to assist maintenance personnel in running and interpreting the diagnostics.

E. Each PTU shall have the software to upload data from the event recorder and display it.

F. Each PTU shall be able to use its web browser and Wi-Fi connection to access all manuals and schematics stored on the repair shop database.

G. Parameter values shall be displayed in decimal format in relevant engineering units (volts, amperes, miles per hour, psig, etc). The PTU shall have the ability to display selected monitoring parameters in chart or graph format.

H. The PTU's shall provide a password protected mode for uploading and verifying new software for each subsystem.

I. Using the PTU interface, it shall be possible to modify configurable parameters for each subsystem while in a password protected mode. The modified values shall revert back to the original default values when the password protected mode is exited.

22.04.04. Diagnostic Test Equipment (DTE)

A. DTE units shall be provided where testing requirements of the system or subsystem are beyond the capability of the PTU. The DTE shall be supplied where direct injection of analog signals or feedback, or direct reading of analog devices or parameters is required. The DTE shall consist of a laptop computer meeting MIL STD 810G, and all the necessary power supplies, inputs, outputs and conditioning equipment required to provide feedback or to input signals to the subsystems' external sensors. It shall also include any other equipment required to test the system and isolate faults to the LRU or external sensor, or to calibrate the system.

B. The DTE's shall be enclosed in aluminum or fiberglass suit case style containers not weighing more than 20 pounds.

C. All equipment provided in the DTE shall be of industrial grade design and suitable for use in a shop and yard environment.

D. The DTE shall include multi-conductor cables to connect to the system under test. Two spare sets of cables shall be provided for each DTE.

E. The DTE shall not connect to any 600 VDC power.

F. The DTE shall be self-protected against shorts and overloads.

G. The DTE shall store all schematics and manuals necessary to assist the repair person in troubleshooting. The DTE shall provide ready access to technical information during testing.

H. Where necessary for the specific subsystem the DTE shall have the ability to run calibration routines and to record the results.

22.04.05. Bench Test Equipment (BTE)

A. For the purpose of this section repairable boards shall be defined as IEEE 16-2004

Category I boards and any peripheral parts of Category II boards which lend themselves to manual probe troubleshooting.

B. BTEs shall be secondary test equipment provided for both intelligent and non-intelligent systems.

C. The BTE shall be provided with all necessary power supplies and shall provide all necessary inputs to fully test the LRU.

D. The BTE shall provide the necessary inputs and probes to isolate repairable printed circuit board failures to the component or group level and to support off-vehicle repair and maintenance activities.

E. BTEs shall be based on a commercially available base hardware platform provided by a BTE manufacturer. The BTE shall include all necessary computers and software for full operation. The BTE computers shall be of a rack mount industrial design.

F. BTEs shall utilize a mass interconnect style connector interface for connection to Units Under Test (UUT).

G. For subsystems for which the LRU is an assembly greater than a printed circuit board, the BTE shall be provided with custom test interface fixtures and cables to allow GO/NO-GO test of the LRU and guided probe isolation of the failed board or subassembly.

H. Two custom interfaces and the necessary cables for interfacing to each sub-system printed circuit board under test shall be provided to allow GO/NO-GO testing. For repairable printed circuit boards, additional probes and test point connections shall be provided to allow guided probe troubleshooting to the component level.

I. For the BTE, the custom interfaces and the test software provided shall enable Authority technical personnel to test the electronic LRU and all associated printed circuits for all electronic microprocessor based subsystems. All test software shall be executed from the BTE and require only cable configuration and the test fixture for the unit under test.

J. The BTE shall be able to:

   1. Observe real time activities of a system and/or subsystem while it is connected to the BTE.

   2. Fully exercise all system functions by injecting signals into the system and subsystem while connected to the BTE and providing a means to verify results.

   3. Verify and calibrate devices while connected to the BTE.

   4. Download fault and memory data from all intelligent systems for later review and processing.

   5. Verify and upload software.

6. Automatically determine if a UUT is working properly.

7. Troubleshoot the LRU down to the printed circuit board.

8. Troubleshoot a repairable printed circuit down to a single component failure for digital circuits and down to a group of 5 or less components for analog circuits.

9. Automatically check the calibration of internal measurement and output devices and attached standard test equipment.

10. Download from a server the results of previous tests to assist the operator in more detailed troubleshooting.

11. Calibrate all electrical or electronic systems or components.

12. Upload the time of test, the identification number of the LRU or printed circuit board under test, the name of the test operator and the results of the current test to a remote server.

13. Print test or calibration stickers in accordance with the Authority's Asset Identification System described above.

K. For repairable printed circuit boards, the BTE shall provide a guided probe approach. The BTE shall direct technical personnel in step by step movement of the probe to identify the fault to the digital component or to a group of five or less analog components. At each step the BTE software shall describe the operation of the part of the circuit being tested and shall display the schematic of the portion of the circuit being tested. For analog circuits, additional support showing acceptable wave forms at each test point shall be provided to permit isolation to the failed analog component. The BTE shall be able to isolate analog circuit problems to 5 or fewer components 98% of the time. The BTE shall be able to isolate digital circuit problems to a single component 95% of the time and 3 or less components 100% of the time.

L. The BTE shall also include commercially available industrial grade test equipment hardware in addition to the hardware provided by the BTE manufacturer.

M. The BTE shall have the capability to provide a continuous loop test signal that shall cycle repeatedly through the circuit under test to facilitate tracing and troubleshooting of intermittent problems.

N. For troubleshooting analog circuits, the BTE or printed circuit board schematics shall display the expected waveform at the indicated test point. This wave form shall be used as acceptance criteria and shall be compared to the actual waveform displayed at the designated test point.

O. The BTE shall be capable of testing any attached test fixture or test cable and of isolating any shorts or opens.

P. The BTE shall be capable of performing a self test of its resident instrumentation and internal components. The BTE shall also be capable of performing a self calibration of all built-in instrumentation and internal measuring devices. The calibration shall be against a removable Peripheral Component Interconnect (PCI) or PCIe based National Institute of Standards and Technology (NIST) traceable standards card.

22.04.06. Power Bench Test Equipment (PBTE)

A. PBTE shall be based on a computer controlled commercially available universal base hardware platform provided by a manufacturer of Bench Test Equipment.

1. Cables, customized test fixtures, power supplies and other equipment used to connect to the unit under test shall be designed to protect the bench test control unit and personnel from high voltage.

2. Where necessary, shields shall be provided to protect personnel from flashes.

B. The Contractor shall survey available power at the Authority's repair shops. Based on this survey the Contractor shall provide all necessary high voltage power supplies, loads and control for testing inverter IGBTs and assemblies.

C. Custom Test fixtures and cables shall be provided for each high voltage converter assembly.

D. The PBTE shall be capable of testing and calibrating itself.

E. The PBTE shall be capable of testing the custom cables and test fixtures for each UUT for shorts and opens. The PBTE shall test for short circuits in cabling and fixtures, and in the UUT prior to application of a high voltage power.

F. The PBTE shall be capable of performing GO/NO-GO tests on each UUT.

G. The PBTE shall be capable of guiding the technician step by step to isolate the faulty component.

H. The PBTE shall be capable of looping a test signal to facilitate the isolation of intermittent problems.

I. The PBTE shall be controlled by software developed in a graphical programming language such as LabVIEW or a similar test development suite with a wide developer base.

J. The PBTE shall include, in addition to the hardware supplied by the bench test equipment manufacturer, commercial industrial grade test equipment suited to the voltage levels to be tested.

K. The PBTE shall be capable of uploading test results to a networked server or to a printer, and of downloading the results or previous tests and saved fault data for use by the operator.

L. The PBTE computer shall store schematics and documentation for all units under test and shall provide access to this material to assist the technician during testing.

M. The PBTE shall be capable of performing a self test of its resident instrumentation and internal components. The PBTE shall also be capable of performing a self calibration of all built-in instrumentation and internal measuring devices. The calibration shall be against a removable PCI or PCIe based NIST traceable standards card.

22.04.07. Automated Test Stands for Mechanical Equipment

A. The contractor shall provide automated test stands for tread brake units, brake valves, door operators, HVAC units and air compressors.

B. The test stands shall be controlled by either PC-based software developed in LabVIEW™ or a similar test development suite with a wide developer base, or by a Programmable Logic Controller with a graphical human/machine interface.

C. The HVAC System Test Stand shall be designed to safely provide the required High Voltage power sources and to simulate temperature inputs to test the operation of the HVAC unit.

D. The test stands shall fully exercise the UUT and monitor it for all known failure symptoms. Test results shall be displayed to the operator. The test stand shall capable of printing test and calibration tags upon completion of the test in accordance with T 22.03 above.

E. The Contractor shall provide the Authority with schematics and drawings for the automated test stands.

22.04.08. Source Code and Development Tools

A. At the end of the warranty period, the source code for the software applications for all BTE, PBTE and automatic test stands shall be turned over to the Authority to use and modifications as may be required for ongoing maintenance of vehicles. [CDRL 22-25]

B. At the end of the warranty period, the Contractor shall provide to the Authority the development tools and licenses necessary to modify all bench test, power bench test and automated test stand application software. [CDRL 22-26]

22.04.09. Delivery of Test Equipment

A. The Contractor or Supplier shall maintain a BTE for each subsystem at the factory site to troubleshoot boards and LRUs found faulty during the acceptance and warranty period. The Contractor or its Supplier shall correct any errors in the software and shall keep records to verify the capability of the BTE to isolate problems in accordance with Bench Test Equipment requirements of this section. These BTEs shall be delivered and installed on the Authority's property at the end of the warranty period. [CDRL 22-27]

B. The second set of BTEs shall be delivered to the Authority and installed 12 months prior to the end of the warranty period for the first Married Pair. [CDRL 22-28] The delivered BTE with the latest software shall be used for training Authority personnel and for troubleshooting failed boards and LRUs during the remainder of the warranty period.

C. The BTE software shall continue to be upgraded until it meets the requirements of this section for ability to detect and isolate board and LRU failures for all subsystems.

D. The PBTE shall be updated throughout the program as is done on the BTE. It shall be delivered and installed 90 days before the end of the warranty period. [CDRL 22-29]

E. The PTUs and DTEs are expected to operate correctly and require no modifications. However, if debugging or modification to software is required, it shall be completed during the qualification test period. The first PTUs and DTEs shall be delivered to the Authority at the same time as the Pilot Cars and shall be fully operational before the acceptance of the first vehicle for revenue service. The full set of PTUs and DTEs shall be delivered together, with all licenses and software, 60 days before the first vehicle enters revenue service. [CDRL 22-30]

F. The automated test stands for mechanical equipment shall be delivered and installed before the delivery of the 30th Married Pair. [CDRL 22-31]

22.05: SPECIAL TOOLS AND EQUIPMENT

22.05.01. General

A. Special tools shall be defined as:

1. Dies, gauges, fixtures, adapters, etc. (excluding a mechanic's set of hand tools or a portable volt-ohm meter).

2. Printed circuit board extenders.

3. Any tool or fixture required for procedures in Running Maintenance or Heavy Maintenance Manuals that is not readily available from a commercial tool supplier shall be considered a special tool.

B. The Contractor shall survey the Authority's existing supply of special tools at the Orange and Red Line repair facilities and at the Authority's main repair facility in Everett, MA. Following the survey, the Contractor shall propose, for Authority review and approval, a list of additional special tools required for maintenance of the fleets. [CDRL 22-32]

C. The Contractor shall provide all the tools on the approved list in the approved numbers 6 months after the delivery of the Pilot Cars. [CDRL 22-33]

22.05.02. Protocol Analyzer

A. The Contractor shall provide a minimum of 6 protocol analyzers with the capabilities described in T 24.11.02, Protocol Analyzer.

B. The protocol analyzers shall be software based running on laptop PTUs.

C. The Contractor shall supply all necessary licenses, installation software and hardware peripherals necessary for implementation of the protocol analyzer function.

D. The protocol analyzer software, installers, peripheral hardware and licenses shall be delivered with the delivery of the PTUs. [CDRL 22-34]

22.06: REPLACEMENT PARTS

22.06.01. Recommended Spare Parts

A. Spare parts shall be provided in accordance with section C6.10.

B. A draft recommended spare parts list shall be submitted to the Authority for review and approval prior to the Authority confirming quantities of Capital Spare Parts as called out in C6.10.B. [CDRL 22-35]

C. The Draft Recommended Spare Parts List shall include recommended quantities of replacement parts, repair parts and overhaul parts.

1. Replacement parts are defined as parts that are scheduled to be replaced on a regular basis and which can be expected to fail randomly.

2. Repair parts are parts which are not expected to fail, but which may reasonably be expected to require replacement from time to time due to accidents, vandalism or abuse.

3. Overhaul parts are parts which are normally replaced on a scheduled basis as part of a system or subsystem overhaul.

D. Overhaul part kits shall be provided for each system or subsystem.

E. The recommended quantities of spare parts shall be based on the estimated reliability of the part or system, the lead times for delivery and the cost of replacement versus repair for each part.

F. A List of Consumable Spare parts with part numbers and expected quantities required based on replacement intervals shall be delivered two months after approval of the design for the Pilot Cars. [CDRL 22-36]

G. Replacement parts that fall under the warranty provisions shall be subject to the requirements of C4.02, Warranty.

22.06.02. Not used

22.06.03. Not used

22.07: USER EDUCATION

22.07.01. Training Program

A. The Contractor shall develop and conduct a detailed, comprehensive training program for Authority personnel in the following course categories:

1. Basic Familiarization
2. Operation and In-Service Training, broken down into modules for each system.
3. Management training with sessions for:
    a. Operations Control Center personnel and Operations managers
    b. Materials coordinators
    c. Maintenance and Central Shops managers
4. Inspection, Service and Maintenance, broken down into modules for each system, service and inspection interval
5. Running Repair and Troubleshooting, broken down into modules for each system.
    a. Network troubleshooting and repair training described in T 24.11, Trainlines and Networks, Maintainability shall also be included.
6. Heavy Repair and Overhaul, broken down into modules for each system.
7. Special Tools and Test Equipment.

B. The Contractor shall submit a Training Program Plan to the Authority, for review and approval, 30 days before Final Design Review for each Line. [CDRL 22-37]

22.07.02. User Education Table

User Education Table					
Session	**Number of Times Each Session is Performed**	**Length of Each Session**	**Students per Session**	**First Session Begins**	**CDRL**
Basic Familiarization	4	1 day	15	Within 30 days of delivery of Pilot Cars	22-38
Operations	6	2 days	15	Within 30 days of delivery of Pilot Cars	22-39
Inspection & Service	4	2 days	15	30 days prior to the Delivery of Pilot Cars	22-40
Management Training Course	3	2	10	At the time of acceptance of the first Married Pair.	22-41

Running Repair	6 OL 12 RL	6 weeks	10	At the completion of Pilot Car qualification testing.	22-42
Overhaul & Heavy Repair	2	4 weeks	10	Within 2 years after the Conditional Acceptance of Pilot Cars	22-43
Special Tools & Test Equipment	4	2 weeks	10	30 days before completion of Pilot Car qualification testing	22-44

Table 22-2 User Education Table

Note - The training listed above is required for each Line, unless stated otherwise.

22.07.03. Training Requirements

A. The training shall include both classroom and field instruction and be organized into modules for specific job categories and departments.

B. The final length of each course and the amount of students per session shall be determined by the Authority based on the content of each module.

C. All training instructors shall be technically knowledgeable in the subject manner, be fluent in English, and shall be experienced trainers and/or trained in adult education training techniques.

D. The Contractor shall provide sufficient laptops for each student and instructor during each training module. The laptops shall include all the necessary cabling and accessories to achieve the training objectives of each module. The Contractor shall provide projectors, screens and any other presentation equipment necessary to facilitate the training.

E. All training shall be held on the Authority's property and scheduled for the day shift. The Contractor shall conduct training classes for the Authority's instructors, supervisory personnel, repair persons and other designated employees.

F. The training shall be based on systems, tasks, and trainee needs. Emphasis shall be placed on safety, complex systems and any systems or tasks that are new or different from current Authority technology or experience. Instruction modules shall include the functionality of each system, subsystem, assembly and component, and the essential elements of their operation and maintenance.

G. Lesson Plans shall be developed for each training class and shall include the following:

1. Student prerequisites, including Authority job classification , prior knowledge, and skills

2. Topics covered with content outline

3. Lesson summary

4. Time frames for instructional units of the lesson

5. Lists of training aids and other training technology

6. Set-up time and lists of equipment for hands-on sessions

7. Safety, protective equipment and hazards

8. Instructor preparation

9. Evaluation of students (tests)

10. Student application of material

22.07.04. Instructor and Student Guides

A. For each course the Contractor shall furnish the following:

1. Instructor guides in three-ring binders containing a series of lesson plans covering all training material for the complete course. The guide shall be divided into class topics and individual presentation units. Instructor guides shall also be submitted on CD-ROMs or DVD ROMs in HTML format. All photos, images and graphics shall be a scanned image in *.TIF format.

a. The Instructor guides shall include:

(1) Table of Contents

(2) Introduction: including course outline, purpose, objective, and testing and evaluation procedures

(3) Class Instructions for each unit of instruction

(a) Class instructions shall include all information necessary for presentation to the class in a logical, systematic approach, student material and handouts, tests and evaluations, administration requirements, time frames, and lesson plans. Class instructions shall explain how best to integrate audio/visual aids and other training technology into each lesson plan.

(4) Index: a complete list of training aids and training technology shall be provided, cross-referenced to the Lesson Plan where they are used.

2. Student Guides shall be in three-ring binders, containing all classroom material required by the student for the course, divided into class topics and individual presentation units. Student Guides shall also be submitted on CD-ROMs or DVD ROMs in HTML format. All photos, images and graphics shall be a scanned image in *.TIF format. The Student Guide shall contain materials necessary to allow for self-study.

B. Draft lesson plans, instructor guides and student guides shall be submitted to the Authority for review and approval no later than 120 days prior to the first scheduled class. [CDRL 22-45] Final plans and guides shall be submitted no later than 60 days prior to the first scheduled class. [CDRL 22-46]

22.07.05. Classroom Supplies

A. The Contractor shall provide all necessary printers and copiers to provide students with classroom materials. All such ancillary equipment shall become the property of the Authority at the conclusion of the Contractor's training program. [CDRL 22-47]

22.07.06. Audio/Visual Aids

A. Audio/visual aids including video, slides, handouts, mock-ups and at least one projector shall be provided. Video presentations shall be provided in DVD format. All training aids and presentation equipment shall be approved by the Authority. Training aids shall become the property of the Authority at the conclusion of the Contractor's training program. [CDRL 22-48]

1. Video recordings from the Maintainability Demonstration shall be provided for training in specialized maintenance tasks and familiarization with the use of test equipment.

2. A video recording of car assembly shall be presented for vehicle familiarization.

3. Refer to C6.09, Training Aids, for further details.

22.08: CDRL ITEMS REFERENCED

CDRL 22-01, "Training Simulator Design", (Ref: T 22.02.08.F) (OPTION)

CDRL 22-02, "Sample Operator's Manual", (Ref: T 22.02.09.A)

CDRL 22-03, "Draft Operator's Manual", (Ref: T 22.02.09.A)

CDRL 22-04, "Interim Operator's Manual", (Ref: T 22.02.09.A)

CDRL 22-05, "Final Operator's Manual", (Ref: T 22.02.09.A)

CDRL 22-06, "Sample Running Maintenance Manual", (Ref: T 22.02.09.A)

CDRL 22-07, "Outline of Vehicle Running Maintenance Manual", (Ref: T 22.02.09.A)

CDRL 22-08, "Draft Running Maintenance Manual", (Ref: T 22.02.09.A)

CDRL 22-09, "Interim Running Maintenance Manual", (Ref: T 22.02.09.A)

CDRL 22-10, "Final Running Maintenance Manual", (Ref: T 22.02.09.A)

CDRL 22-11, "Sample Heavy Maintenance Manual", (Ref: T 22.02.09.A)

CDRL 22-12, "Draft Heavy Maintenance Manual", (Ref: T 22.02.09.A)

CDRL 22-13, "Interim Heavy Maintenance Manual", (Ref: T 22.02.09.A)

CDRL 22-14, “Final Heavy Maintenance Manual”, (Ref: T 22.02.09.A)

CDRL 22-15, “Sample Maintenance Planning Manual”, (Ref: T 22.02.09.A)

CDRL 22-16, “Draft Maintenance Planning Manual”, (Ref: T 22.02.09.A)

CDRL 22-17, “Final Maintenance Planning Manual”, (Ref: T 22.02.09.A)

CDRL 22-18, “Sample Test Equipment Manuals”, (Ref: T 22.02.09.A)

CDRL 22-19, “Draft Test Equipment Manuals”, (Ref: T 22.02.09.A)

CDRL 22-20, “Final Test Equipment Manuals”, (Ref: T 22.02.09.A)

CDRL 22-21, “Sample Illustrated Parts Catalog”, (Ref: T 22.02.09.A)

CDRL 22-22, “Draft Illustrated Parts Catalog”, (Ref: T 22.02.09.A)

CDRL 22-23, “Interim Illustrated Parts Catalog”, (Ref: T 22.02.09.A)

CDRL 22-24, “Final Illustrated Parts Catalog”, (Ref: T 22.02.09.A)

CDRL 22-25, “Delivery of Source Code for All Testing Systems”, (Ref: T 22.04.08.A)

CDRL 22-26, “Development Tools and Licenses for Testing Systems”, (Ref: T 22.04.08.B)

CDRL 22-27, “Delivery of First Set of Bench Test Equipment”, (Ref: T 22.04.09.A)

CDRL 22-28, “Delivery of Second Set of Bench Test Equipment”, (Ref: T 22.04.09.B)

CDRL 22-29, “Delivery of Power Bench Test Equipment”, (Ref: T 22.04.09.D)

CDRL 22-30, “Delivery of Portable and Diagnostic Test Equipment”, (Ref: T 22.04.09.E)

CDRL 22-31, “Delivery of Automated Test Stands”, (Ref: T 22.04.09.F)

CDRL 22-32, “Special Tools and Equipment Survey”, (Ref: T 22.05.01.B)

CDRL 22-33, “Delivery of Special Tools and Equipment”, (Ref: T 22.05.01.C)

CDRL 22-34, “Delivery of Protocol Analyzer Software and Equipment”, (Ref: T 22.05.02.D)

CDRL 22-35, “Draft Recommended Spare Parts List”, (Ref: T 22.06.01.B)

CDRL 22-36, “List of Consumables”, (Ref: T 22:06.01.F)

CDRL 22-37, “Training Program Plan”, (Ref: T 22.07.01.B)

CDRL 22-38, “Basic Familiarization Training”, (Ref: T 22.07.02)

CDRL 22-39, “Operation Training”, (Ref: T 22.07.02)

CDRL 22-40, “Inspection and Service Training”, (Ref: T 22.07.02)

CDRL 22-41, “Management Training”, (Ref: T 22.07.02)

CDRL 22-42, “Running Repair Training”, (Ref: T 22.07.02)

CDRL 22-43, “Overhaul and Heavy Repair Training”, (Ref: T 22.07.02)

CDRL 22-44, “Special Tools and Test Equipment Training”, (Ref: T 22.07.02)

CDRL 22-45, “Draft Lesson Plans Instructor and Student Guides”, (Ref: T 22.07.04.B)

CDRL 22-46, “Final Lesson Plan Instructor and Student Guides”, (Ref: T 22.07.04.B)

CDRL 22-47, “Ancillary Classroom Supplies”, (Ref: T 22.07.05.A)

CDRL 22-48, “Audio/Visual Training Aids and Equipment”, (Ref: T 22.07.06.A)

22.09: REFERENCES

22.09.01. Standards Referenced

ATA iSpec. 2200, Information Standards for Aviation Maintenance.

IEEE Std. 91-1984, Explanation of Logic Symbols.

22.09.02. Technical Specification Cross References

T 16, Vehicle Monitoring System
T 24, Trainlines and Networks

PART T 24.00
TRAINLINES & NETWORKS

Table of Contents

24.01: GENERAL

A. The Contractor shall develop a trainline and network list that identifies trainline and vehicle signals and functions. The list shall indicate the transmission method used for each signal and define whether it is a discrete trainline or network transmission. The trainline and network list shall be submitted to the Authority for review and approval prior to the final design review. [CDRL 24-01]

B. The Contractor shall designate a single supplier as having system integration responsibility for the trainline networks. The selected supplier shall have successful prior rail industry experience in performing such integration. The Contractor shall submit the selected integrator to the Authority for review and approval. [CDRL 24-02]

C. The Contractor shall ensure that all trainline components and networks are designed to provide proper operation of trainlined functions for train lengths of up to 12 cars.

D. The trainline design shall permit operation from any cab or hostler panel in the train.

E. The Contractor shall ensure that all trainline signals function reliably across automatic coupler contacts without requiring additional coupler maintenance.

F. The Contractor shall provide fault tolerant networks that have the ability to maintain communications between connected nodes without loss of data in the event a single open or short circuit.

G. All networks shall be based on the 7 layer Open Systems Interconnection (OSI) model. Full documentation of each layer for each network shall be provided in a Network Interface Control Document to be submitted prior to Preliminary Design Review. The document shall be updated with all changes through testing and the end of the warranty period. [CDRL 24-03]

H. All discrete trainlines and p-wire current loop signals shall be redundant through the left and right coupler heads.

I. The routing of the train-line and network cables shall be selected to protect them from mechanical damage and flying track bed debris.

24.02: SYSTEM DESCRIPTION & CONFIGURATION

24.02.01. General

A. Train and vehicle communication and control shall be achieved through:

1. Discrete trainlines or a p-wire current loop for critical functions such as propulsion and brake control, door control, door and brake interlocks, holding off emergency braking, etc.

2. A fault tolerant digital network fully compliant with IEEE 802.3 for all diagnostic, communication and other functions. Any safety critical Category I or II functions shall have a fully redundant hardware bypass.

3. Provisions shall be made to allow the Authority to add a train to wayside communication unit that will allow access to any end station or node on the digital network via a VPN connection.

24.02.02. Electromagnetic Compatibility

A. The Design of the Networks detailed in this section shall consider the effects of common mode noise typically found in electrified rail vehicles with AC propulsion and static converters. The Contractor shall develop a Network Electromagnetic Compatibility Plan which shall identify the susceptibility limits of each network to noise. The Network EMC Plan shall take into account the real field conditions including coupler pin oxidation issues, third rail gaps, circulating inverter currents, etc. [CDRL 24-04]

24.03: DIGITAL NETWORKS

24.03.01. Topology and Architecture

A. An Ethernet based using IEEE 1473:2010 or later Type E network as a starting point shall be utilized to support the transmission of diagnostic, control functions, audio, video, and passenger information. The network shall contain redundant trainline connections to ensure high availability. Alternate network architecture may be proposed if approved by the Authority.

B. The Contractor shall use Internet Protocol version 4 for all addressing, management and communication services. Internet Protocol version 6 may be implemented only if full support can be demonstrated for all IP enabled devices and network equipment.

C. The IP address scheme shall be based on EN IEC 61375. The IP addressing scheme shall require approval by the Authority (CDRL 24-05)

D. The DIGITAL NETWORK shall consist of the Married Pair Networks (MPM linked to a Train Network (TN).

E. All devices connected to the MPN shall be referred to as End Stations (ES).

F. All End Stations shall be connected to the Married Pair Ethernet Network through Vehicle Switches (VS).

G. The Vehicle Switches (VS) shall be connected to each other through a fault tolerant ring topology to form the Married Pair Network(MPN).

H. The Married Pair Network (MPN) shall be connected to the Train Network (TN) by links to the Train Switch in each car of the Married Pair.

I. The Train Switches within each Married Pair shall be connected by redundant 100 BASE TX links. The Train Switches shall manage traffic between the Married Pair

Network and the Train Network and shall manage redundant communication to other Married Pairs across the electrical couplers.

J. The Contractor shall provide a description of the Digital Network control and architecture for Authority review and approval. This description shall include detail on the data network protocols, fault tolerance, degraded operating modes, redundancy arbitration, error detection, and a description of network initialization and configuration. [CDRL 24-06]

K. The Contractor shall submit a list of all IP devices on the Digital Network to the Authority for review and approval. [CDRL 24-07]

24.03.02. Systems Connected to Digital Network

A. It is expected that all intelligent vehicle systems will be connected to digital network this shall include, but not be limited to, the following:

1. Propulsion
2. Friction brake
3. HVAC (each unit)
4. Auxiliary inverters
5. Low Voltage Power Supplies
6. Door control
7. Vehicle Monitoring Unit (VMU)
8. ATP/ASR
9. Event Recorder System (ERS)
10. Communication System

24.03.03. Network Switches

A. General

1. All IP switches shall be designed to support Ethernet Frame switching as per IEEE 802.1D, Quality of Service as per IEEE 802.1Q, Virtual Local Area Network as per IEEE 802.1Q, Link Layer Discovery Protocol as per IEEE 802.1AB. Switches shall provide sufficient buffering and queuing capability to avoid network bottlenecks. Use of proprietary protocols is prohibited.

B. Vehicles Switches (VS)

1. The Contractor shall provide sufficient Vehicle Switches per married pair to manage the MPN traffic and to support redundancy.

C. Train Switches (TS)

1. The Train Ethernet Network shall have redundant 100 BASE-TX full duplex links between the train switches. The Contractor shall provide train switches to manage the link redundancy and to maintain the network communications in the event of a link failure. The train switch shall be a standalone unit.

2. Each train switch shall implement a bypass function to maintain the train network continuity in case of a train switch failure.

3. Power Over Ethernet (POE) switches may be provided if approved by the Authority.

24.03.04. Network Nodes

A. All vehicle network End Stations (ES), Switches, etc., shall implement a unique device ID using an external static ID scheme that shall indentify the device independently of its IP address. The purpose of this requirement is to allow the system to know the type and physical location of devices without any configuration when devices are replaced.

24.03.05. Network Cables

A. The Contractor shall provide shielded CAT5e/ CAT6e cables that are in compliance with the smoke and flammability requirements specified in T 18.19, Flammability, Toxicity, and Smoke Emissions, for all Ethernet networks.

B. All cable connections to subsystems and switches shall be made using crimped M12 connectors. Use of RJ 45 (8P8C) connectors for network connections is prohibited.

24.03.06. Train Network Through the Coupler

A. The Ethernet network shall communicate successfully with other nodes through coupler interface pins, without limitation as to the sequence or orientation within the train, without requirement for manual configuration and without loss of data.

B. The Contractor shall select coupler pin assignments and coupler pin types to ensure the best signal to noise ratio and greatest throughput with the lowest bit error rate. The Contractor shall submit the selected locations and pin types to the Authority for review and approval. [CDRL 24-08]

C. The Contractor shall take into consideration the worst-case data transmission conditions created by the use of the electrical coupler system described in T 04, Coupler and Draft Gear. The contractor shall develop a plan that takes into consideration the signal voltage level and rise time. The Contractor shall propose a method not necessarily compliant with IEEE 1473:2010 to obtain reliable operation though the coupler. The method for transmission through the coupler shall be based on open standards and shall be fully documented. The Contractor shall submit to the Authority for review and approval a plan that describes the method proposed to obtain reliable transmission through the coupler together with a risk assessment prior to the preliminary design review. [CDRL 24-09]

24.04: SAFETY CRITICAL TRAINLINES

24.04.01. Emergency Trainline

A. An Emergency Trainline shall be provided to hold off application of the Emergency Friction Brakes and to permit powering of the Traction Inverter gate drivers and the propulsion system Line Contactor. This discrete trainline shall be of a double break design with vital control of the positive and negative energy. The Emergency Trainline may be de-energized by:

1. ATP unit
2. Any Operator's Emergency Mushroom Switch
3. The Active Master Controller
4. Loss of Emergency Brake Pipe Pressure
5. Any Passenger Emergency Stop (PES)

B. Activation of any PES or Operator's Emergency Mushroom Switch shall be reported the Vehicle Monitoring Unit (VMU) of the Married Pair and displayed on all Vehicle Monitoring Displays (VMD).

C. Activation of any PES shall activate a trainline which shall cause the Passenger Emergency Stop indication LED to illuminate on the Operator's Console. The PES indication trainline shall also prevent a reset of the Emergency Trainline until the Passenger Emergency Reset Switch on the Operator's Console is activated.

24.04.02. Door Control Trainlines

A. Two discrete trainlines shall be provided for opening the doors on each side of the train. Both the Door Open Left and the Door Unlock Left trainlines must be energized to command the doors to unlock and open on the Left Side of the train. Both the Door Open Right and the Door Unlock Right trainlines must be energized to command the doors to unlock and open on the right side of the train. Both the Door Open and Door Unlock trainlines shall be controlled by the Door Open switch in the Door control panel on the left or right side of the cab set up for door control.

24.04.03. Doors Closed Summary Trainline

A. The Doors Closed Summary Trainline shall be provided to interlock the propulsion system such that tractive effort shall not be applied and brakes released unless all doors are closed and locked. The Doors Closed Summary Trainline shall also be used to control the Doors Closed Indicator LED on the Operator's Console.

B. The Doors Closed Summary Trainline shall be a discrete trainline designed so that it cannot be defeated by false energy on a single wire.

C. A sealed door interlock bypass switch shall be located in each cab but shall be effective only when activated in the Married Pair with the active cab or hostler panel. Refer to T 05.03, Cab Controls, and T 06.03, Door Controls.

24.05: COUPLING, PROPULSION CONTROLS AND DISCRETE TRAINLINES

24.05.01. P-wire loop

A. The P-wire shall be a regulated current loop with current proportional to power or brake request with a coast zone in the middle. The P-signal generator in the Automatic Speed Regulation (ASR) Module of the ATP/ASR unit shall be capable of reliably driving all connected readers and any coupler pin contact resistance that would be added when connected to a 12-car train-set.

1. The P-wire current level corresponding to maximum power request shall be at least 100 ma rms.

B. The Contractor may propose a network alternative for Authority review and acceptance provided that:

1. The network alternative can be shown to be more reliable than the P-wire loop design currently used on the Authority's Red Line #3 car.

2. The network alternative shall allow the propulsion and braking systems to meet the response time requirements of T 02.02.05, Response Times.

3. That the network alternative is as fail-safe as the P-wire loop.

24.05.02. Power/Brake Mode Trainline

A. A Power/Brake Mode Trainline shall be provided as redundant indication that must agree with the mode requested by the P-wire loop. Otherwise the propulsion and braking systems shall implement a full service brake application.

24.05.03. The All Brakes Released Trainline

A. An All Brakes Released Trainline shall be supplied that informs the trainline control logic in the lead car that all brakes are released on the train.

B. Loss of the All Brakes Released Trainline signal when trainlines are configured for application of power shall, after a preset time delay, cause the active cab to issue trainline commands for removal of power and full service brake application. The time delay shall be coordinated with the roll back function to prevent re-application of brakes during start up.

C. Loss of the All Brakes Released Trainline shall cause the Brake Fault indication light to illuminate on the cab console of the controlling cab. Refer to T 05.03, Cab Controls.

D. A sealed brake interlock bypass switch shall be provided in each cab, but shall have an effect only when activated in the Married Pair with the active Master Controller or Hostler Panel.

24.05.04. Couple/Uncouple

A. The Contractor shall provide circuits across the coupler to control the electrical and pneumatic coupling and uncoupling of the train set. The couple and uncouple trainlines shall be controlled by the Couple, Uncouple Trainline and Uncouple Mechanical switches in the Operator's Cab. The trainlines provided shall be:

1. The Couple Trainline is only active between two mechanically mated cabs. The Couple Trainline is activated by the Couple switch in the Operator's Cab. Activation of this trainline causes the electrical coupler heads on both couplers to move forward and make contact. Activation also causes the trainlines to be configured for a middle car. For detailed description of operation refer to T 05, Operator's Cab and T 04, Coupler and Draft Gear.

2. The Uncouple Trainline is only active between two mated cabs. Activation of the Uncouple Trainline causes the electrical coupler heads to retract on both mated couplers and configures the train lines for an end car. For further details refer to T 05, Operator's Cab and T 04, Coupler and Draft Gear.

3. The Uncouple Trainline is only active between two mated cabs. Activation of the Uncouple Mechanical causes the couplers to mechanically unlatch. It can only be activated when the cabs are already electrically uncoupled and configured as end cars. For further details refer to T 05, Operator's Cab and T 04, Coupler and Draft Gear.

B. All Coupler controls are interlocked with the No Motion Relay.

24.05.05. Trainline and Network Functions That Operate When Train Control Is Uncoupled

A. The Contactor shall provide a means of operating the Bell Trainline, Battery Negative and the Digital Network through the coupler even when the train control trainlines are electrically uncoupled. The purpose of this feature is to allow crew audio communications during pushing or towing a train which may have trainline problems.

24.05.06. Discrete and Analog Trainlines

A. A list of discrete and analog trainlines is provided in the table below.

B. The Contractor shall add any additional trainlines required for safe, reliable operation of the train.

C. Discrete and analog trainlines shall be redundant through the left and right electrical coupler heads.

Trainline	**General Description**
Emergency Brake	The Emergency Brake Trainline shall be a double break (breaks + and -) trainline which holds off venting of the Emergency Brake Pipe by the Emergency Magnet Valves, holds off removal of power from the Traction Inverter Gate Drivers and allows the Traction Line Contactor to be energized.
Passenger Emergency Stop Indication	The Passenger Emergency Stop Indication Trainline is enabled whenever any PES is activated. This trainline illuminates the Passenger Emergency Stop Indicator LED on the Operator's Console. Activation of this trainline shall prevent resetting of the Emergency Trainline until the Passenger Emergency Reset Switch on the Operator's Console is activated.
P-Wire Loop	The P-wire shall be a regulated current loop with current proportional to power or brake request with a coast zone in the middle. The p-signal generator in the Automatic Speed Regulation (ASR) Module of the ATP/ASR unit shall be capable of reliably driving all connected readers and any coupler pin contact resistance that would be added when connected to a 12-car train-set. Maximum Power request shall be equivalent to at least 100 ma rms P-wire current.
Slide Control Enable	Loss of power on this trainline shall inhibit slide control. This trainline shall be used to inhibit slide control in emergency braking under selected initiation conditions.
Propulsion and Brake Mode	The Propulsion/Brake Mode trainline shall provide a redundant indication that must agree with the mode requested by the P-wire loop. Otherwise the propulsion and braking systems shall implement a full service brake application.
Regeneration Cutout	The Regeneration Cutout trainline shall be activated by the sealed Regeneration Cutout Switch in the Operator's cab. This trainline inhibits regeneration of power back to the third rail or other systems during braking on all cars in the train.
Forward	The Forward Trainline shall be activated by the Forward position of the Master Controller Direction Switch in the active cab or hostler panel. This Trainline permits train movement in the forward direction.
Reverse	The Reverse Trainline shall be activated by the Reverse position of the Master Controller Direction Switch in the active cab or hostler panel. This trainline permits train movement in the reverse direction.
Sleet Scraper	The Sleet Scraper Trainline is activated by the Sleet Scraper switch on the Operators Console in the Active Cab. This trainline commands the deployment of all sleet scrapers in the train and activates the snow brake/sleet scraper lights in the controlling cab and the exterior snow brake/sleet scarper lights on all cars.
Interior Light control	Command for interior lights Refer to T 08, Lighting.

Trainline	**General Description**
Snow Brake	The Snow Brake Trainline is activated by the Snow Brake switch on the Operator's console of the active cab. This trainline commands all Friction Brake Control Units to apply snow brakes as described in T 12, Friction Brakes & Pneumatic System, and activates the snow brake/sleet scraper light in the controlling cab and the exterior snow brake/sleet scraper lights on all cars.
Train Shutdown	The Train Shutdown Trainline is activated by the Train Shutdown switch on the Operators console. Activation of this trainline causes all cars to remove low voltage DC Both LVPS units shall monitor battery temperature and charging current and shall regulate voltage within the battery manufacturer's requirements power from all systems except Emergency Lights. This trainline may only be activated when all Master Controllers in the train are in the Store and Off position. Power shall be restored when any Master Controller is keyed on.
Cab Control	The Cab Control Trainline is initiated from the Master Controller or Hostler Panel of the controlling car and locks out train control from all other cabs or hostler panels.
Bell	The Bell Trainline activates the bells in all Operators' Cabs for emergency train crew communications. The Bell Trainline is Controlled from the Operator's console. It shall be possible to utilize this trainline function even when all train control functions are disabled through the coupler as occurs when towing a dead train.
Buzzer	The Buzzer Trainline shall be activated by Buzzer pushbutton in the left or right Door Control Panel in the cab set up for Door Control. The Buzzer Trainline shall activate the door system buzzer in all other cabs.
Doors Closed Summary Trainline	The Doors Closed Summary Trainline is a summary circuit that indicates all side doors and ramps are closed and locked and that the Door Enable Trainlines are disabled. The Doors Closed Summary Trainline permits traction power to be generated and friction brakes to be released. This Trainline shall be designed such that it cannot be defeated by false energy on a single wire. The Doors Closed Summary Trainline shall also control the Doors Closed indicator light on the Operator's Console.
Doors Open Left Side	Both Doors Open and Doors Unlock signals are required to unlock and open the doors. Both signals initiated from the Left Side Doors Open Push button in Door Control Cab.
Doors Unlock Left Side	
Door Open Right Side	Same as Door Open Left Side and Door Unlock Left Side, but for the right.
Doors Unlock Right Side	

Trainline	General Description
Doors close Left Side	The Door Close Left Side Trainline is initiated from the Doors Close pushbutton on Left Side Door Control Panel in the Door Control Cab. This trainline commands all left side doors and ramps to close. Activation of this trainline also cancels the Door Enable Left Trainline.
Doors Close Right Side	Same as Door Close Left, but for the right side.
Door Enable Left	Door Enable Left is a trainline signal provided to permit local opening of left side doors from the left side Passenger Door Request Buttons. The Door Enable Left trainline shall be initiated by the Door Enable Push Button in Left Side Door Control Panel of the cab set up for door control. . The Door Enable function shall be cancelled when the Door Close Left Trainline is activated or when No Motion Signal goes false. . The Door Enable Left Trainline cannot be activated or read when the train is in motion.
Door Enable Right	Same as Door Enable Left, but for the right side
All Brakes released	All Brakes Released is a summary Trainline that informs the controlling car that all brakes are released on the Train-set. . For detailed function of this trainline Refer to T 24.07.03, All Brakes Released Trainline, T 12, Friction Brakes & Pneumatic System and Air Supply.
Battery Minus	Battery Minus Trainline provides a common reference for trainline functions. Low Voltage Distribution Network grounding must be implemented in a way that minimizes traction return current flow on this bus below interference levels. . This trainline shall be active through the coupler interface even when coupler is in an end car configuration.
HVAC Shutdown	The HVAC shutdown is initiated by a switch on the Operator's console of the controlling cab. When activated this trainline causes all HVAC systems in the train to shut down.
Couple	The Couple Trainline is only active between two mechanically mated cabs. The Couple Trainline is activated by the Couple switch in the Operator's Cab. Activation of this trainline causes the electrical coupler heads on both couplers to move forward and make contact. Activation also causes the trainlines to be configured for a middle car.
Uncouple Trainline	The Uncouple Trainline is only active between two mated cabs. Activation of the Uncouple Trainline causes the electrical coupler heads to retract on both mated couplers and configures the train lines for an end car.
Uncouple Mechanical	The Uncouple Mechanical is only active between two mated cabs. Activation of the Uncouple Mechanicalcauses the couplers to mechanically unlatch. It can only be activated when the cabs are already electrically uncoupled and configured as end cars.

Table 24-1 Discrete and Analog Trainlines

24.06: DIAGNOSTICS AND MONITORING

24.06.01. Self Test and Fault Monitoring.

A. The network systems shall include self-test and monitoring features that automatically identify defective nodes and links.

B. Network faults on shall be reported to the Vehicle Monitoring System.

24.06.02. Portable Test Unit Access

The contractor shall proved a Universal Service Port (USP) to allow maintenance personnel to comment a laptop and access any end station, or switch on the vehicle or in the consist, through an industrial D coded M12 connector conveniently located in the cab.

1. A software or web access system shall be provided that will permit graphical display of the health of the entire network and all nodes and switches.

2. The software or web access system shall enable Authority personnel to retrieve fault logs, run diagnostics or make configuration changes on any selected node.

24.07: PERFORMANCE

24.07.01. Traffic Capacity and Bit Error Rates

A. All networks shall have capacity 50 % above the expected worst case in service load without any degradation of performance.

B. The Train Ethernet Network transmission through the electrical coupler shall have the capability to simultaneously support four 800 x 600, 10 frame per second video streams plus a PEI session and PA and sign announcements with no visible or audible delays.

C. The Bit error rate of all networks shall be less than 1×10^{-9}.

24.07.02. Integration and Fault Tolerance Testing

A. Contractor shall perform a Network Interface Card (NIC) test of each end station or switch to verify compliance to IEEE standards

B. The Contractor shall perform a complete network integration test of all train subsystems, including transmission through the electrical coupler to determine the network noise limits, and to pre-qualify the proposed architecture of networks before vehicle implementation. This test shall consist of a simulated 12 car train with all train switches, actual cable and cable length, coupler pins and connectors that will be used on the vehicles. All intelligent system controls connected to the digital shall be the actual units in one married pair, the other cars may use simulated traffic generators. These tests shall also verify that the protocols, datasets and messages used on all networks correspond to the Network Interface Control Document and the specific signal, message and dataset documentation provided for each network. At the time of the integration tests, the Contractor shall also demonstrate the fault tolerance of all networks by simulating all possible faults. The Authority shall have the option of witnessing the tests. The test procedures [CDRL 24-10] and results [CDRL 24-11] shall be submitted to the Authority for review and approval.

24.07.03. Testing Discrete Trainlines

A. All discrete trainline wires shall be point-to-point tested and insulation resistance tested in accordance with T 20, Testing and Validation.

B. All discrete trainlines shall be functionally tested during the factory system test to prove they meet the requirements of Table 24-1, Discrete and Analog Trainlines.

24.08: RELIABILITY

24.08.01. Network and Trainline Reliability

A. The Contractor shall, in accordance with Network Electromagnetic Compatibility Plan required by this section, ensure that no other network or vehicle or wayside system can cause unreliable network transmission.

B. The Contractor shall demonstrate that a maximally worn coupler shall not disrupt network transmission through the coupler. Network communications shall remain reliable on curves and hills with no increase in bit error rate or reduction in throughput.

C. The networks shall be designed to minimize the possibility that a transceiver component fault could disable the network. Transfer of communications to redundant links or networks shall be automatic in the case of the failure of a node or link.

D. Mean Distance Between Component Failures for trainlines and networks as a whole shall be greater than 300,000 miles, given regular 90 day maintenance of coupler pins.

24.09: MAINTAINABILITY

24.09.01. Network Test Points

A. All networks shall be provided with test points conveniently located in the cab that allow monitoring and testing of the network without dismantling any equipment or cabling.

24.09.02. Protocol Analyzer

A. The Contractor shall provide a laptop based Protocol Analyzer for Authority use to perform real-time monitoring of network activity on all networks provided under this contract. The Protocol Analyzer shall have the capability of:

1. Displaying data in engineering units.

2. Setting of capture filters to limit the recording of telegrams to only the ones that are targeted.

3. Providing a visualization of the protocol stack in adjustable levels of detail.

4. Developing and displaying statistical reports on traffic, errors, protocol types, etc.

5. The Contractor shall submit for Authority review and approval the capabilities of the Protocol Analyzer for each Network. [CDRL 24-12]

24.09.03. Node Replacement

A. When nodes on the network are replaced using parts supplied by the Contractor or the equipment supplier, the network system shall automatically identify the replacement equipment and its communication links.

B. Replacement of networked subsystem controllers shall not require any configuration of the controller, or of vehicle/train switches.

C. Replacement of any Vehicle or Train Switch shall not require more than 20 minutes when performed by a single person.

24.09.04. Training

A. The Contractor shall provide training to Authority personnel in:

1. The theory of operation of train and vehicle networks, including the principles underlying the physical layer, protocols, device addressing and message formats.

2. Troubleshooting network problems using network management software and the Protocol Analyzer.

3. Use of an oscilloscope to locate the source of network noise and reflection problems.

4. Troubleshooting discrete trainlines.

5. Recommended procedures for repairing network cables and termination of network wiring and shielding.

24.09.05. Maintainability Design and Demonstration

A. The Contractor shall design networks and trainlines in accordance with the maintainability requirements of T 02.04, Vehicle Design Requirements, Maintainability.

B. The Contractor shall meet the Maintainability Demonstration and Pilot Train Maintainability requirements of T 02.04, Vehicle Design Requirements, Maintainability.

24.10: SAFETY

24.10.01. Safety Analysis

A. The Contractor shall perform a Failure Modes Effect and Criticality Analyses (FMECA) that demonstrates the safety of all critical discrete and analog trainlines. [CDRL 24-13]

B. The Contractor shall perform a failure mode analysis related to network component failure and data corruption. All single-point failures that could render a train control or critical communication function inoperative or unsafe shall be detailed for the Authority's review and approval. [CDRL 24-14]

24.10.02. Network Isolation and Security

A. The Contractor shall provide an analysis of the potential effects of various possible security attacks on network transmissions and the operation and effectiveness of the measures taken to ensure the security and the safety of the networks. The security analysis shall be guided by IEC/ISO 27000 series standards. This document shall be submitted for Authority review and approval. [CDRL 24-15]

24.11: COMPATIBILITY

A. The Contractor shall arrange coupler pins and trainline circuits in a manner that will permit mechanical coupling to an existing Red Line or Orange Line car without causing damage to the electrical coupler heads or dangerous malfunction of trainlines.

B. Network equipment for Red Line and Orange Line vehicles shall be interchangeable.

24.12: CDRL ITEMS REFERENCED

CDRL 24-01, “Trainline and Network List”, (Ref: T 24.01.A)

CDRL 24-02, “Integrator Selection”, (Ref: T 24.01.B)

CDRL 24-03, “Network Interface Control Document”, (Ref: T 24.01.G)

CDRL 24-04, “Network Electromagnetic Compatibility Plan”, (Ref: T 24.02.02.A)

CDRL 24-05, "IP Addressing Scheme", (Ref: T 24.03.01.C)

CDRL 24-06, “Communication Network Control and Architecture”, (Ref: T 24.03.01.J)

CDRL 24-07, “Communications Network IP Device List”, (Ref: T 24.03.01.K)

CDRL 24-08, “Train Network Coupler Pin Assignments”, (Ref: T 24.03.06.B)

CDRL 24-09, “Train Network Transmission through the Coupler”, (Ref: T 24.03.06.C)

CDRL 24-10, “Network Integration Testing Procedures”, (Ref: T 24.07.02.B)

CDRL 24-11, “Network Integration Testing Results”, (Ref: T 24.07.02.B)

CDRL 24-12, “Protocol Analyzer Features and Capabilities”, (Ref: T 24.09.02.A.5)

CDRL 24-13, “Discrete and Analog Trainline FMECA”, (Ref: T 24.10.01.A)

CDRL 24-14, “Failure Mode Analysis of Network Components”, (Ref: T 24.10.01.B)

CDRL 24-15, “Network Security Analysis”, (Ref: T 24.10.02.A)

24.13: STANDARDS REFERENCED

IEEE Std. 1473- Type “E”, Standard for Communications Protocol Aboard Train

IEEE 802.1D, Quality of Service

IEEE 802.1Q, Virtual Local Area Network

IEEE 802.1Q, Link Layer Discovery Protocol

IEEE 802.1ABand provide sufficient buffering and queuing capability

24.14: TECHNICAL SPECIFICATION CROSS REFERENCES

T 02, Vehicle Design Requirements
T 04, Coupler & Draft Gear
T 05, Operator's Cab
T 06, Passenger Doors & Controls
T 08, Lighting
T 12, Friction Brakes & Pneumatic System
T 13, Communications & Passenger Information System
T 16, Vehicle Monitoring System
T 18, Materials & Workmanship
T 20, Testing & Validation

PART T 25.00
EVENT RECORDER

Table of Contents

25.01: GENERAL

A. Independent of the Vehicle Monitoring System, the Authority requires a separate Event Recorder in each Cab Car.

B. The Event Recorder shall record all safety critical data and allow retrieval after any incident or unsafe event.

C. Event Recorders shall meet the requirements of IEEE Std. 1482.1-1999, Standard for Rail Transit Vehicle Event Recorders.

D. A detailed functional description of the event recorder shall be submitted for Authority review and approval. [CDRL 25-01]

25.02: SYSTEM DESCRIPTION & CONFIGURATION

25.02.01. Location and Hardening

A. The Event Recorder shall be installed in the car interior above the floor, in a secure location, inaccessible to unauthorized personnel, but easily accessible for inspection and replacement by Authority maintenance personnel. The location shall be approved by the Authority. [CDRL 25-02]

B. The Event Recorder shall be fully environmentally hardened (i.e., fire, water and explosion proof).

25.02.02. Power

A. The Event Recorder shall be powered from the battery backed up Low Voltage Distribution Network through a dedicated, magnetic, push to reset circuit breaker which cannot be turned off.

   1. The Event Recorder shall not be subject to load shedding in the case of failure of the Low Voltage Power Supply.

25.02.03. Network Interfaces

A. The Event Recorder shall have interfaces for the Digital Network described in T 24.03, Digital Networks, in order to:

   1. Report its health status to the Vehicle Monitoring Unit (VMU).

   2. Receive vehicle parameters from the measuring subsystems.

   3. Report to the VMU the vehicle parameters which are measured independently of other systems.

25.02.04. Data Recorded

A. As a minimum, the following data and signals shall be recorded:

1. Mandatory channels from IEEE Std. 1482.1-1999
2. Master Controller power or brake request
3. Status of the Inching Switch
4. Brake Cylinder Pressure for each truck in the Married Pair
5. Snow Brake Status
6. Parking Brake Status
7. Car Number (from car wiring)
8. Hostler Panel Active
9. Dead Man control
10. Emergency Trainline
11. Activation of the Emergency Brake Mushroom
12. Passenger Emergency Stop Status
13. Slide control activation
14. Doors Closed Summary status
15. Traction/Braking demand (P –wire signal level and power/brake mode trainline or equivalents)
16. Speed (From propulsion logic or an independent speed sensor and from the ATP/ASR system)
17. No Motion Status
18. Trip Cock Activation
19. Third rail voltage
20. Horn
21. Voltage to Headlights
22. Monitoring and Train Control Network serial faults
23. Status of all Bypass switches
24. Brake Cut Out Status
25. Tractive Effort level (both positive and negative)

26. ATP/ASR Operating mode (Automatic Speed Regulation, Manual, Manual Release, Hostler Release, Emergency Bypass)

27. Additional Signals from ATP

    a. Overspeed status

    b. Emergency Overspeed status

    c. Acceleration/de-acceleration rate

28. Status of Wayside Worker Warning System

    a. Transmitting

    b. Alarm Active

29. Three (3) spare digital channels

30. Three (3) spare analog channels

B. Where the Event Recorder reads signals used by other subsystems, this shall be done in a manner that failure of the Event Recorder shall not disable the other subsystems.

C. The Event Recorder shall not power any device used by any other system.

25.02.05. Data Storage and Retrieval

A. Data storage shall be First In, First Out (FIFO), such that the latest information is retained.

B. All data recorded shall be date and time stamped in accordance with IEEE STD 1482-1999.

C. A crashworthy removable memory module shall store the data.

D. Data retrieval shall be also available through an Ethernet port:

   1. Retrieval of data shall not delete data from the internal crashworthy memory module.

E. The contractor shall provide software that shall allow a user to use a laptop computer to download event data over an Ethernet port. The software shall support display of parameter data in chart or text format. The software shall also allow the user to plot speed versus time, even during slides using acceleration data and the last known speed.

F. Data retrieval shall also be available via a Universal Serial Bus (USB) flash memory drive.

25.03: PERFORMANCE

25.03.01. General

A. The sampling and storage rate shall comply with the requirements specified in IEEE Std. 1482.1-1999.

B. The contractor shall provide a systems integration document that details how parameters from the same event shall be reported in a time synchronized manner.

25.04: COMPLIANCE AND COMPONENT TESTING

25.04.01. General

A. Prior to installation on the Pilot Car, the first Event Recorder shall be qualification tested to ensure that the system performs in accordance with the specification.

B. Test procedures shall be submitted for Authority review and approval. [CDRL 25-03]

C. Test Reports shall be submitted for Authority review and approval. Unit First Article Inspection (FAI) acceptance shall be subject to successful completion of the Qualification Tests. [CDRL 25-04]

25.04.02. Bench Tests

A. Contractor shall demonstrate compliance of the Event Recorder with the Specification requirements. If the Event Recorder proposed is service proven and fully meets the requirements of this contract, the Contractor may provide, in lieu of testing, the test results of previous contracts for Authority consideration.

B. The first Event Recorder shall be subjected to testing that demonstrates:

1. Compliance with the requirements of IEEE Std. 1482.1-1999, Standard for Rail Transit Vehicle Event Recorders.

2. Event Recorder’s functional capability to record all required data correctly.

3. Capability to retrieve data with a laptop Portable Test Unit through the Ethernet port provided and displayed, as specified.

4. Capability to retrieve data with a USB flash memory drive.

25.04.03. Production Tests

A. Each Event Recorder shall be subjected to a production test at the Contractor’s manufacturing facility.

B. Production tests shall be conducted to demonstrate that each unit is functioning properly and ready for installation and operation on Authority vehicles.

25.05: RELIABILITY

A. The Event Recorder, including the crashworthy memory module, shall have a Mean Time Between Component Failures of 225,000 hours or greater.

25.06: MAINTAINABILITY

A. Contractor shall demonstrate the Event Recorder accessibility for removal, replacement and maintenance.

B. The Event Recorder shall comply with the design and demonstration requirements of TS 02.04, Vehicle Design Requirements, Maintainability.

25.07: SAFETY

A. The Event Recorder shall have automatic self test, as outlined in IEEE Std. 1482.1-1999.

B. The Event Recorder shall be passive (shall not process data).

C. The Event Recorder shall provide an LED indication when recording.

D. Speed, distance, selected direction, emergency brake application status, wayside worker warning system status, signal aspect, Bypass switch status, tractive or braking effort request, brake cylinder pressure and motor current shall be obtained directly or from the units monitoring these variables, not from the Vehicle Monitoring System.

25.08: COMPATIBILITY

A. All subassemblies and components shall be:

1. Interchangeable between the Red and Orange Line vehicles.

2. Of the same manufacturer and part number.

25.09: CDRL ITEMS REFERENCED

CDRL 25-01, “Functional Description of the Event Recorder”, (Ref: TS 25.01.D)

CDRL 25-02, “Location of the Event Recorder”, (Ref: TS 25.02.01.A)

CDRL 25-03, “Test Procedures”, (Ref: TS 25.04.01.B)

CDRL 25-04, “Test Reports”, (Ref: TS 25.04.01.C)

25.10: REFERENCES

25.10.01. Standards Referenced

IEEE Std. 1482.1-1999

25.10.02. Technical Specification Cross References

T 02, Vehicle Design Requirements
T 18, Materials & Workmanship
T 24, Trainlines & Networks