SMART
Technical Specification for Diesel Multiple Units (DMUs)

Draft for Industry Review

January 20, 2010

Notes to the Industry Reviewer

This document is a draft specification for Diesel Multiple Units (DMUs) for the Sonoma Marin Area Rail Transit (SMART) project. SMART intends to procure up to 22 individual vehicles and is seeking input from potential proposers, regulators, and other stakeholders prior to releasing this specification in a Request for Proposal (RFP). This should not be construed as an RFP or commitment by SMART to the procurement of DMUs or as a final version of the specification. Input has been sought from other SMART stakeholders and two public workshops have been held. However, due to the timing of the industry review, some of the input from the public has yet to be included in this version of the specification. Public input from those workshops will be combined with responses obtained in this industry review phase, during the next revision.

SMART desires a vehicle that is safe, efficient, comfortable to ride in, environmentally friendly, and aesthetically pleasing. It is recognized that the procurement size requires a certain degree of flexibility in vehicle design, and this specification is geared more towards the performance of the vehicle and the standards by which it is constructed, rather than the specific components, control schemes, and features. Potential proposers are encouraged to make suggestions that make the vehicle more consistent with the previously mentioned SMART desires. SMART also encourages potential proposers to make recommendations that make the vehicle more commercially viable, thus opening the market for future orders for the proposer, possibly lowering the initial cost to SMART.

Three concept sketches have been included. They do not represent a final design, but serve to help the reviewer understand the various elements represented in the specification. The first sketch is the basic DMU. The second sketch is a married pair showing virtually identical DMUs with the exception being the lavatory in one vehicle and the service bar in place of the lavatory in the other. This service bar concept is still under review at SMART. The third sketch is a three-car train in which the center car is not identical to the DMU. It has no cab and may or may not be powered. This maximizes the seating in a three-car train, which is SMART's current maximum train length. SMART is interested to hear how many center cars must be ordered to make procurement practical. This center car concept is not part of the base SMART model and is currently undergoing a feasibility analysis.

The SMART team has prepared a list of specific items for which comments would greatly assist in the final preparation of the RFP:

- The traditional high level boarding platform is at 48 inches above top of rail (ATOR), but most vehicle floors are at 51 inches. Is it practical for the carbuilder to deliver a vehicle that can provide ADA-compliant level boarding at 48 inches ATOR or even less?

- Given the constraints of California General Order 26d, platform heights above 8 inches ATOR require setbacks that would make traditional level boarding impossible without the use of a siding or gauntlet track. What practical modifications can be made to the railcar to bridge a large gap (up to 30 inches) to the platform, without sacrificing dwell time or service reliability?

- Will the requirement for EPA Tier 4 engines present a risk to the carbuilder given the intent to award a contract by the end of 2010?

- SMART is interested in keeping this DMU service as environmentally friendly as possible. What are the options of using biodiesel, while still maintaining Tier 4 compliance?

- If a diesel electric drive is proposed, will it be possible to easily convert the vehicle into a dual mode vehicle at a later date, to be able to operate under a 1500Vdc catenary and diesel?

- Would a serial electric drive make it easier to comply with EPA Tier 4 requirements?

- What features could be added to the vehicle to recover energy during braking and how do they affect vehicle cost?

- What would be the operational benefits of an energy storage system?

- Would the use of energy storage reduce the size of the diesel generator needed to supply power to the electric drive?

- What is a practical expectation for design and construction of pilot cars, testing of pilot cars, and delivery of remaining vehicles?

- How practical is a modular seating arrangement in which seating arrangements could be reconfigured for changing ridership needs? Two possibilities should be considered; removing seats routinely to allow for more open space during weekend operation, and reconfiguring seating one time based on trends established during the first months or years of operation.

- SMART is expecting that many passengers will travel with a bicycle on these DMUs. How is the carbuilder suggesting to maximize bicycle space without impacting the seating capacity too much?

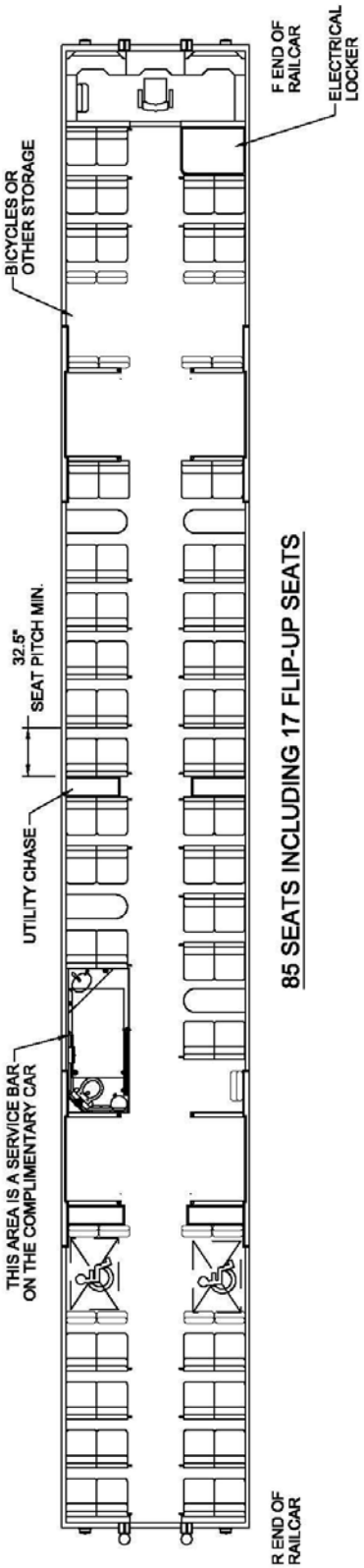
- Does the recent FRA commitment to streamlining the waiver process and their stated intent to allow operation of CEM-equipped vehicles to operate without traditional temporal separation create an opportunity for the carbuilder to propose an alternate design? If so, what product might be offered?

- Is there any clarification required for FRA compliance items, such as safety appliances, PTC, or QMP training?

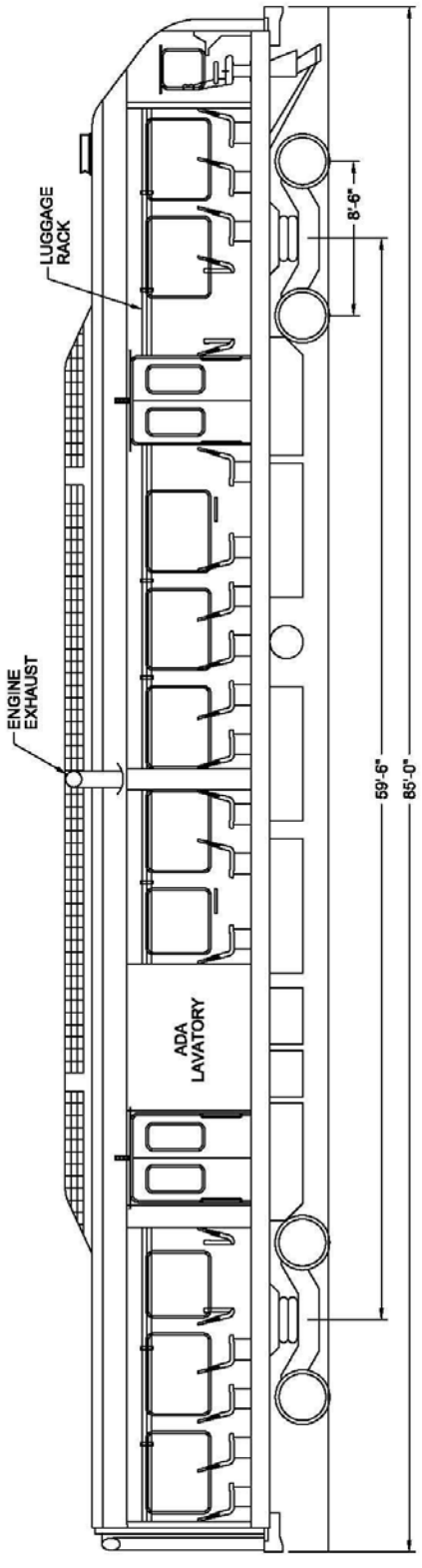
- The DMU structure is to be FRA compliant. In addition to that level of protection, what CEM features can be offered?

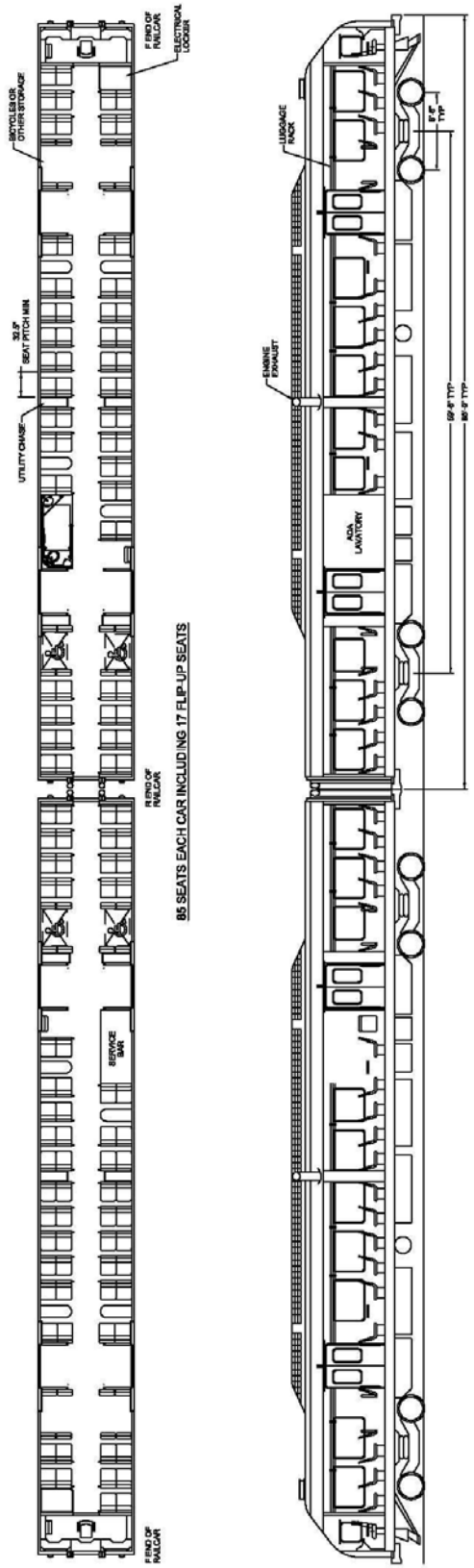
- Recommendations are welcome for complying with California GO 53162, which requires storing of video for at least one year.

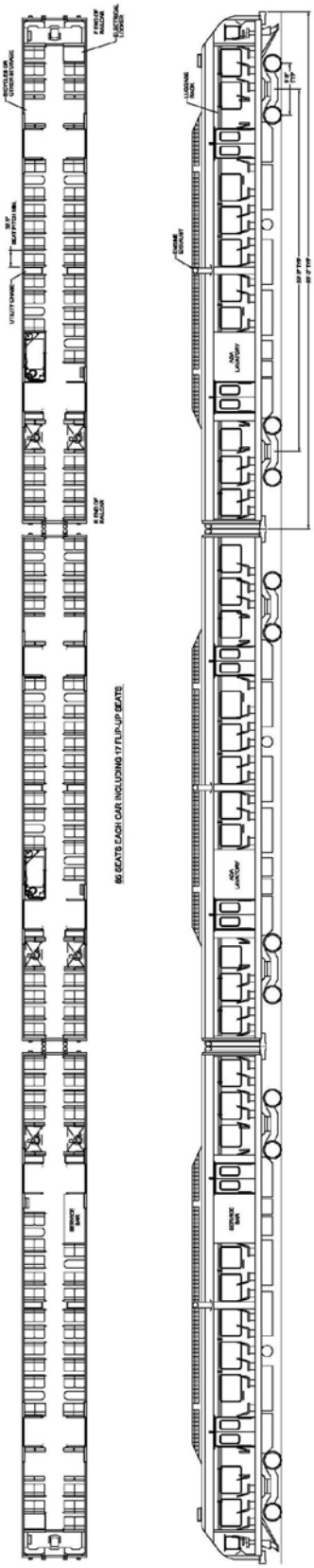
- What is the additional cost of fully complying with California GO 53162, versus storing video for 2, 4 weeks?



85 SEATS INCLUDING 17 FLIP-UP SEATS




F END OF RAILCAR
ELECTRICAL LOCKER
BICYCLE OR OTHER STORAGE
32.5" SEAT PITCH MIN
UTILITY CHASE
R END OF RAILCAR
SERVICE BAR
F END OF RAILCAR
85 SEATS EACH CAR INCLUDING 17 FLIP-UP SEATS
LUGGAGE RACK
5'-0" TYP
ENGINE EXHAUST
ADA LAVATORY
82'-6" TYP
85'-0" TYP


86 SEATS EACH CAR INCLUDING 17 FLIP-UP SEATS

Revision History

Rev. #	Section	Description	Date	Approved
0	NA	Draft Submittal for Industry Review	1-15-09	dad
Draft	Multiple	Minor corrections prior to release	1-20-09	dad

Revision 0 QC History

Section	Title	Author	Checked by	Back Checked	Verified
1	General	Uttinger	DiBrito	Uttinger	DiBrito
2	Vehicle Requirements	Uttinger	DiBrito	Uttinger	DiBrito
3	Carbody	Cameron	Roman	Cameron	DiBrito
4	Coupler	Cameron	Takeda	Cameron	Takeda
5	Operator's Cab	Elliott	Uttinger	Elliott	Uttinger
6	Doors	Krause	Uttinger	Krause	Uttinger
7	Heating and Ventilation	Levin	Schwab	Levin	Schwab
8	Lighting	Krause	Uttinger	Krause	Uttinger
9	Auxiliary Electric	Krause	Uttinger	Krause	Uttinger
10	Propulsion/Dynamic Brakes	Parker	Uttinger	Parker	Uttinger
11	Electronic Controls and MDS	Sanders	Uttinger	Sanders	Uttinger
12	Trucks	Cameron	Takeda	Cameron	Takeda
13	Friction Brakes	Uttinger	Elliott	Uttinger	Elliott
14	Communications	Krause	Elliott	Krause	Elliott
15	Operational safety (PTC & ATC)	Elliott	Mathews	Elliott	Mathews
16	System Safety	Turner	Elliott	Turner	Elliott
17	Materials and Workmanship	Cameron	Roman	Cameron	Roman
18	Testing	Parker	Elliott	Parker	Elliott
19	System Support	Elliott	DiBrito	Elliott	DiBrito
20	Quality Assurance	Turner	Hong	Turner	Hong

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1 GENERAL REQUIREMENTS

This specification addresses the procurement of Diesel Multiple Units (DMUs) for the Sonoma Marin Area Rail Transit District (SMART). The SMART corridor extends from Larkspur, California north approximately 70 miles to Cloverdale, with 12 intermediate stations. SMART intends to operate these self propelled vehicles in minimum train lengths of two cars, to allow bi-directional operation of the consist. While married pairs are acceptable, autonomous vehicles coupled at the non-cab end are the most flexible, given the fleet size and spare vehicle availability. Thus, the sharing of systems between cars is allowed but not encouraged, unless substantial benefit to SMART can be proven. Maximum train length is envisioned to be three cars but the systems must be capable of supporting operation of a six car train. SMART desires a sleek modern design with an aerodynamic cab end. SMART also desires a design that is environmentally friendly and that provides a comfortable, quiet ride for its passengers. The Contractor is encouraged to consider these desires when choosing components, features, and overall design elements.

The Contractor shall design, manufacture, test and deliver the products as described by this specification. Potential vehicle contractors may propose alternative design values, with the final design subject to approval by SMART.

The Contractor is responsible for the design and integration of all vehicle systems such that all specified requirements are achieved without conflict or error within or between systems. The Contractor shall ensure that all designers, suppliers, and subcontractors are informed of all specified requirements and that appropriate engineering management tools are utilized to ensure that coordination and communication occurs between the designers of inter-related systems.

Name brands, specific equipment, or specific materials may be referenced in this specification. Such equipment has been shown to be successful in previous applications, where correctly applied and integrated with other equipment; however, such references shall not be interpreted as pre-approval of any Contractor designs or applications. The Contractor is responsible for the selection, application, and integration of equipment and materials as necessary to comply with the specified requirements.

All equipment provided under this Contract shall be new. Rebuilt or refurbished equipment is prohibited. New equipment damaged during execution of this Contract may be restored to new condition only where approved by SMART on a case-by case basis, and all restorations shall be performed by the original equipment manufacturer.

If not mentioned otherwise, the following design criteria are considered for a single car or for each single car, forming a married pair.

1.1 Contract Deliverables

This specification requires the submittal of drawings, documents, system descriptions, analyses, test results, manuals and similar information for review by SMART to verify compliance with specified requirements, and for after-delivery support of the vehicles. Submittal requiring approval are identified in each Section.

Other specific submittal requirements are listed at the conclusion of each section under “CDRL”. Typically, the CDRL submittals relate to the design requirements in any given sections. The Contractor is obligated to forward them for review and approval even though they may not appear in the CDRL section.

1.2 Abbreviations

To be added for the final release

1.3 Definitions

- DMU: Diesel Multiple Unit. A DMU is a diesel-powered, self-propelled passenger railcar that can respond to local or remote throttle and brake commands. DMUs will be combined with other DMUs to form a train consist.
- Train Consist: A combination of one or more railcars coupled together and operated by one train crew. The smallest revenue service train consist would be two vehicles.
- Single Car: A single carbody that is an autonomous unit or functions as one half of a married pair.
- Married Pair: Two single cars semi-permanently coupled together to form one autonomous unit. Married pairs may share equipment if needed.
- Articulated Pair: Two single cars permanently coupled by an LRT style articulation.
- Vehicle: One autonomously operating unit. Could be a single car, a married or articulated pair.

The list of definitions will be expanded in the final RFP release.

1.4 General Vehicle Description

The vehicles shall be diesel self propelled vehicles configured as single car or as married or articulated pair, capable of running up to 79mph on FRA track grade 4.

1.5 Train Consist

The minimum train consist shall be two vehicles, although a single vehicle should be able to operate autonomously. Larger train consists can be formed by coupling married pairs and/or singles (depending on technology and proposed vehicle configurations) in combination, but not exceeding 300 feet.

1.6 Code Compliance and Compatibility with Railroad Requirements

The train consist shall be fully compliant with the FRA rules as documented in the Code of Federal Regulations (CFR), in particular Title 49, Parts 200-299. Vehicles shall also comply with applicable standards and recommended practices as issued by the American Public Transportation Association (APTA), Association of American Railroads (AAR), and Americans with Disabilities Act (ADA) 49 CFR 38.

Alternate vehicle designs that meet FRA specified criteria, currently under development by the Railway Safety Advisory Committee, (RSAC) for waiver of the crashworthiness requirements in 49 CFR 238, will be considered. In such cases, the Contractor shall provide evidence prior to contract execution that the vehicle design meets these criteria, and that the vehicle will not be subject to temporal separation when operating on SMART's right-of-way. Waivers for items outside the regulations addressed by RSAC, including glazings, safety appliances, fire safety, etc will not be allowed.

The train consist shall be fully compatible with all aspects of the SMART commuter rail alignment.

1.7 Environmental Conditions

Normal operation of the vehicles in the Marin and Sonoma County environment shall not in any way impair the performance or useful life.

Tmax =	45C (113F)
Tmin =	-10C (15F)
Wind maximum speed	130 km/h (80mph)
Annual rainfall	< 510mm (20")
Maximum rainfall:	51mm (2")
Humidity	10% to 100%
Moisture Acidity	pH 4.0
Fog conditions	low adhesion

1.8 Train Crew Size

The train crew is planned to be one operator and one conductor, regardless of consist size. The operator will be stationed in the leading cab while the conductor is located in the passenger areas. If two vehicles are coupled, there shall be a passage way for the conductor between the vehicles, unless otherwise approved by SMART.

1.9 Fare Collection Methods

No on-vehicle fare collection system is required. Wayside vending machines will sell or validate tickets while on-board fare inspectors may perform spot checks of

passengers. The vehicles do not require any special provisions for fare collection.

1.10 Onboard amenities

1.10.1 Restroom

One car in a married pair or articulated vehicle shall be equipped with one ADA compliant restroom.

1.10.2 Snack bar

One car in a married pair or articulated vehicle shall be equipped with a snack bar, capable of serving snacks and drinks. The snack bar shall be designed to be reconfigured into a seating area at any time in the future, if necessary. It is preferred that the snack bar be located in the same place as the restroom on the adjacent car.

1.10.3 Bicycles

There shall be an area to transport bicycles near at least one door of each car. Space for at least 4 bicycles per car shall be available. Bicycle areas may be equipped with fold down seats for multi purpose use.

1.10.4 Wheel Chairs

Each car shall be fully ADA-compliant, including two wheel chair parking locations near the doors. These locations may be equipped with fold down seating to allow for multi-purpose use. Wheel chair parking shall also be configured in a way that coordinates with easy access to the restroom, entry doors, and companion seating.

2 GENERAL VEHICLE REQUIREMENTS

This section lists the general vehicle requirements. Any deviation from these values will require SMART approval.

2.1 General Vehicle Description

The vehicles shall be designed for top speed of 79 mph.

The vehicles shall be able to run in multiple units. They shall be equipped with automatic couplers allowing a quick coupling and decoupling.

There shall be an aerodynamic full-width cab at one end of each vehicle.

The vehicles shall be sized such that some multiple is as close to 300 feet in length without exceeding that value. This will maximize the number of passengers that can be carried in a consist that still fits within a 300-foot station.

The intended service life of all car types shall be 30 years.

2.2 Dimensions

2.2.1 Carbody Dimensions

Basic carbody dimensions for a single car are shown below and represent current commuter rail vehicle design practice. Deviations from these values must be approved by SMART:

Table 2-1
Basic Carbody Dimensions

Dimension	Value
Nominal overall single car length	85 feet
Maximum carbody exterior width over side sheets	10 feet, 6 inches
Maximum carbody exterior width over side door thresholds	10 feet, 0 inches, +/- ¼ inch
Nominal coupler height above rail	34-½ inches
Minimum clearance above top-of-rail for all carbody elements (except wheels) under all conditions	2-¾ inches
Floor height above top-of-rail	< 51 inches
Maximum height of roof-mounted equipment	14 feet, 8 inches
Nominal height of central high ceiling above floor	7 feet, 3 inches
Minimum height of low ceiling above floor	6 feet, 9 inches
Minimum side door clear opening, width	51 inches
Minimum side door clear opening, height	6 feet, 6 inches

Dimension	Value
Minimum end door clear opening, height (if applicable)	6 feet, 4-¾ inches
Minimum aisle width, clear (except ADA affected areas)	20-¾ inches
Minimum aisle width, clear (in ADA affected areas)	32 inches
Nominal interior width (at armrest height)	10 feet, 0 inches
Maximum height of bottom of window glass, above floor	30 inches
Minimum height of window opening	40 inches
Minimum Window length	50 inches
Minimum seat pitch	32-½ inches
Minimum hip-to-knee space between non-facing seats	30 inches
Design value for spring failure body sway	4 degrees
Design value for normal operational body sway	2.5 degrees
Design value for truck and carbody roll center	22 inches above TOR
Design value for lateral truck suspension shift	2 inches

2.2.2 Truck Dimensions

Basic truck dimensions are:

Table 2-2
Basic Truck Dimensions

Dimension	Value
Nominal truck center spacing	< 59 feet, 6 inches
Nominal axle center spacing	< 8 feet, 6 inches

2.2.3 Wheel Dimensions

Wheels shall use a narrow-flange profile with a 1:40 tread taper. Other profiles may be proposed, subject to approval by SMART.

Table 2-3
Wheel Dimensions

Dimension	Value
Nominal wheel diameter	36 inches
Maximum wheel wear (on diameter)	3 inches
Wheel gauge, back to back	53-⅜ inches
Minimum worn flange width	7/8 inch

2.2.4 Track Characteristics

Minimum track grade will be FRA class 4 (for the full speed range)

Station platforms heights will be matched to the finally selected vehicle design. The smallest station will have maximum platform length of 300 feet.

Rail types:	TBD	
Minimum horizontal curve radius:	250 feet	
Minimum vertical curve, crest:	2000 feet	
Minimum vertical curve, sag:	2000 feet	
Track gauge:	4 feet 8-1/2 inches	
Maximum sustained gradient:	3 %	
Reverse vertical curves:	TBD	
Compound curves:	TBD	
Turnout	TBD Crossover	TBD

2.3 Car Weight and Passenger Loading

Five levels of car weights are referenced within these design documents. For design calculations, passengers are assumed to weigh 165 pounds per person.

Table 2-4
Car Weights

Abbreviation	Definition	Weight (lbs)
AW0	Empty car operating weight	< 160,500
AW1	Fully seated passenger load, one operator and one conductor, plus AW0	
AW2	Standees at four passengers per square meter of suitable standing space plus AW1 (Structural mean fatigue load, Propulsion performance load)	
AW3	Standees at six passengers per square meter of suitable standing space plus AW1 (Braking performance load)	
AW4	Standees at eight passengers per square meter of suitable standing space plus AW1 (Structural design load, not contemplated for revenue operation)	

Passenger loading should average at least 80 seated passengers per car. Suitable standing space shall be defined at all areas of the aisles where it is possible for passengers to stand.

Each car type shall have a maximum end-to-end imbalance not to exceed 5%. The lateral weight imbalance shall not exceed 40,000 inch-pounds.

The carbuilder shall provide estimated vehicle weights and passenger loadings. If the contract is awarded, a vehicle weight schedule shall be submitted to SMART on a regular basis. (CDRL 01)

2.4 Clearances

2.4.1 Track Clearance Envelope

The cars shall comply with Amtrak 1355, Revision E, both static and dynamic clearance diagrams, as provided in Figures 1 through 3 below.

Amtrak 1355 E defines a dynamic clearance envelope for the carbody under the full range of suspension motions but on level, tangent track. A complete dynamic clearance envelope calculation must also consider lateral wheel/rail motion, cross level variation, superelevation, and horizontal and vertical curvature.

2.4.2 Undercar Clearance

Vertical undercar clearance is defined from top-of-rail (TOR), with the maximum suspension deflection and carbody roll, minimum vertical curve radius and fully worn wheels. The minimum clearance above TOR for all carbody and truck elements, except wheels, under all conditions shall be 2-3/4 inches.

A clearance of at least 1-1/2 inches, exclusive of positive stops, shall be provided between truck parts and carbody parts under the most unfavorable conditions of

truck curvature, wheel wear, lateral and vertical motion and roll, and broken and/or deflated springs.

Figure 1
Vehicle Static Clearance Limits from Amtrak 1355 Revision E

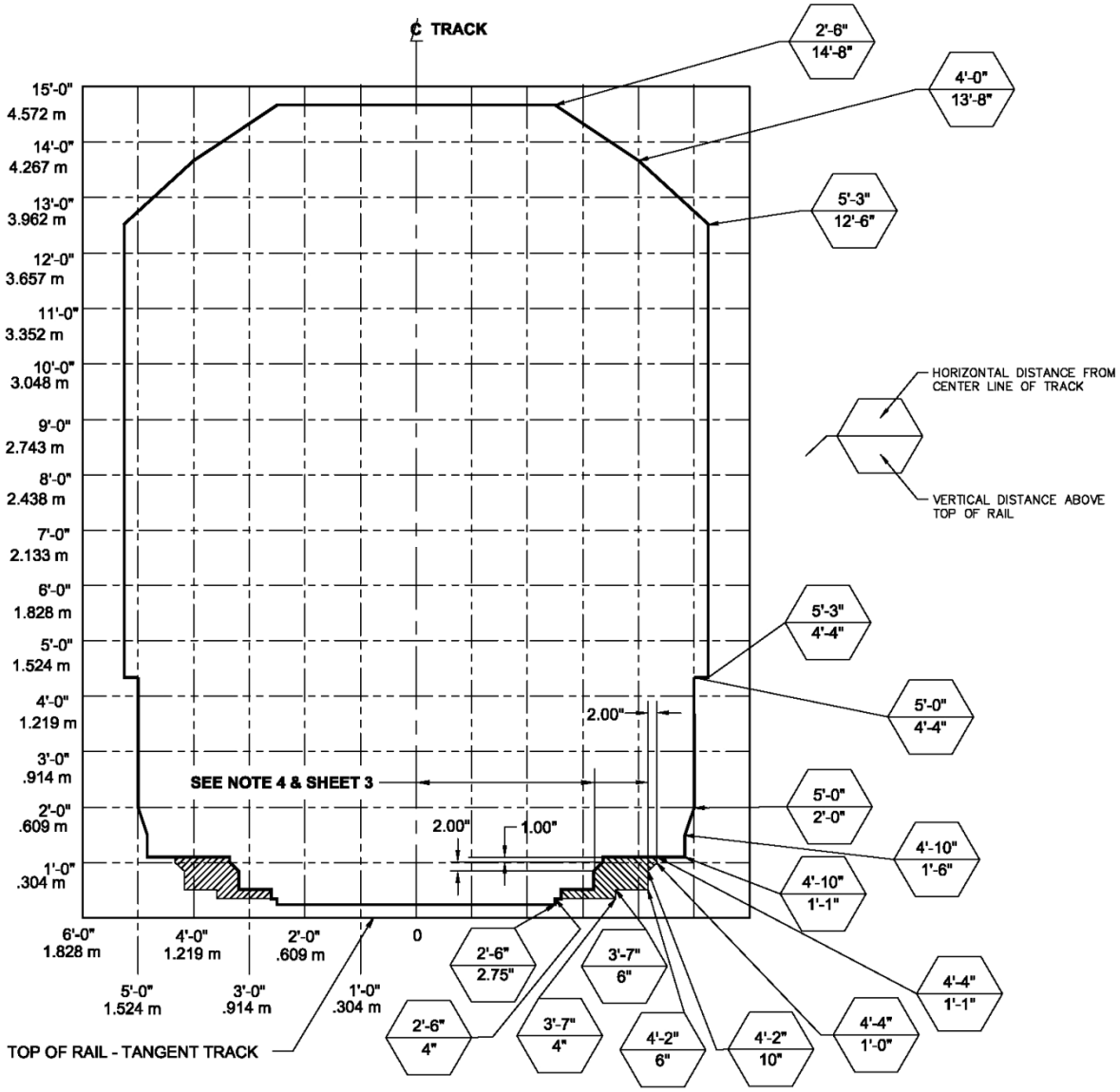


Figure 2
Vehicle Dynamic Clearance Limits from Amtrak 1355 Revision E

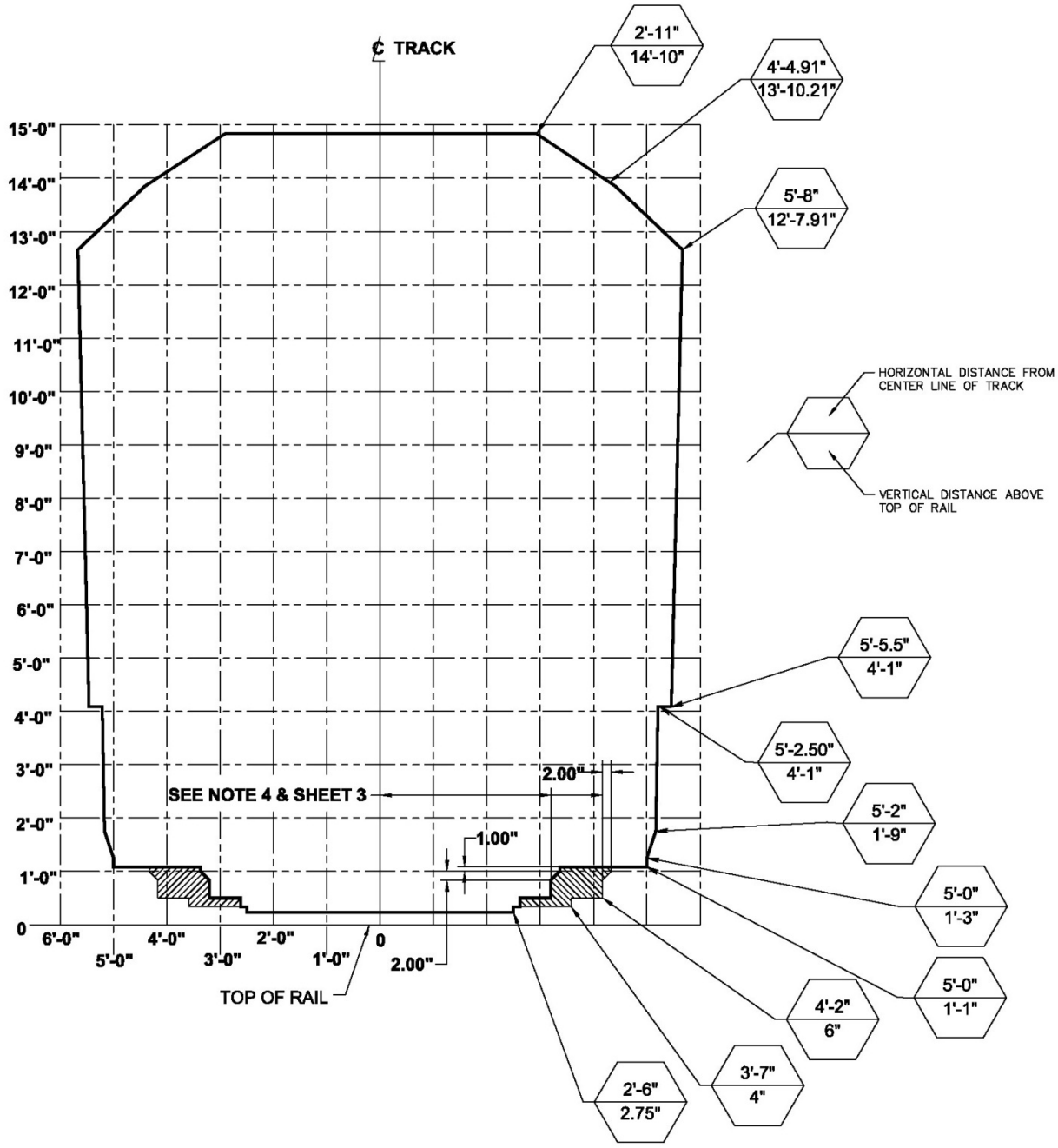
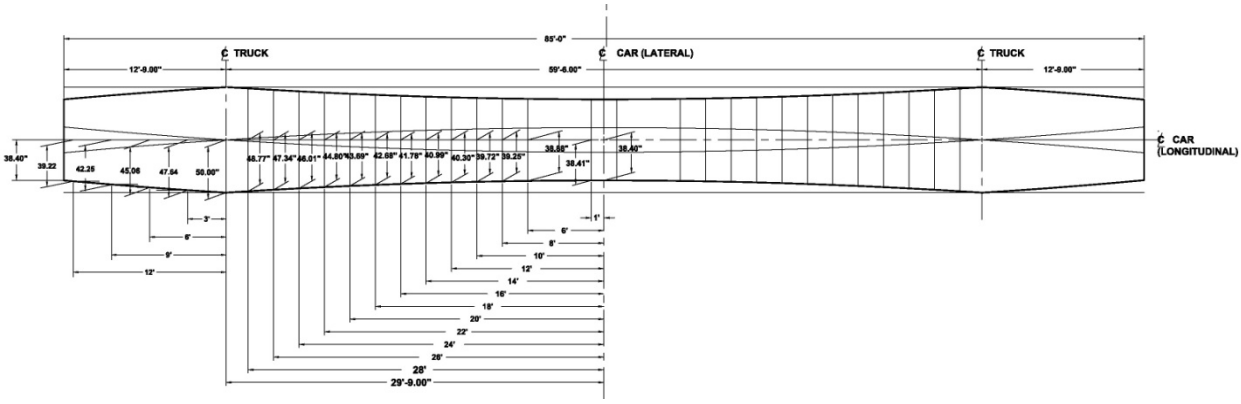
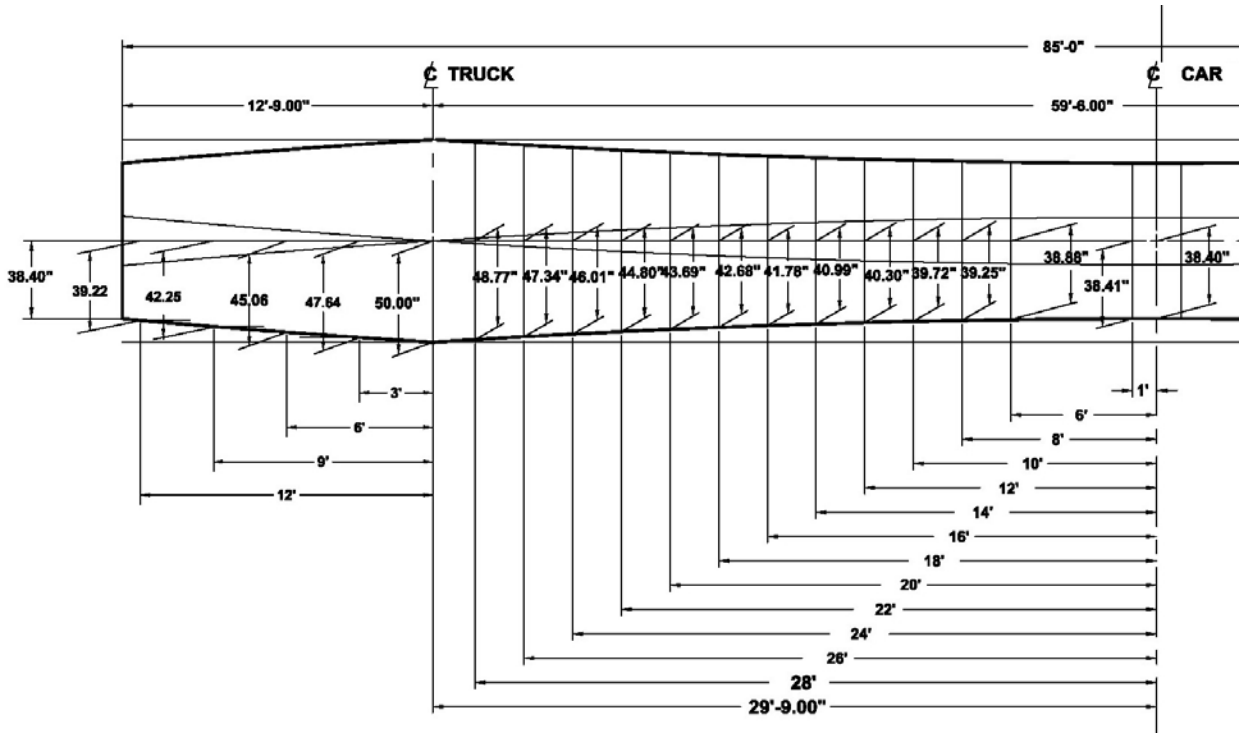


Figure 3
Vehicle Undercar Curve Clearance Limits from Amtrak 1355 Revision E



Detail magnified for clarity



2.5 Performance

2.5.1 General

Cars shall be designed for the following speeds:

Table 2-5
Design Speeds

Condition	Speed
Maximum revenue operating speed	79 mph (worn wheels)
Design speed	90 mph (new wheels)

2.5.2 Route Performance

Simulations shall be performed for an AW2-loaded consist, traveling the whole alignment from Larkspur to Cloverdale (70 miles) in less than 1 ½ hours. The simulated alignment must be based on the latest grade, curvature, and speed limit data available from SMART. Intermediate station dwells shall be modeled at 45 seconds. The maximum auxiliary load must be considered. Simulation results, including fuel consumption calculations, shall be submitted to SMART for review and approval. CDRL 02

The consists shall have a maximum end-of-route turn time of 7 minutes. The turn time shall allow the operator to disable and leave one cab, walk to the other end of the consist, set up that cab, perform an FRA-compliant Class II brake test, and be ready to depart the station.

2.5.3 Duty Cycle Rating

The car shall be capable of continuous operation on the alignment without exceeding the continuous rating of any equipment, under the following conditions:

- A constant AW2 load;
- A dwell time of 45 seconds at each intermediate station;
- Acceleration and braking at maximum service rate;
- Travel from Larkspur to Cloverdale in less than 1.5 hrs (without layover times)
- Operation to maximum posted track speeds; and
- A seven minute layover at each end of the line.

In addition, the vehicles shall be able to operate with 50% of the propulsion and braking available under the following conditions: An operating AW3 loaded car shall be capable of towing an inoperative AW3 loaded car with the brakes released (not functional) from the point of failure to the next station, where passengers would be unloaded. Rescue would continue with both trains at AW0

to the end of the line, at reduced performance if need be, without damage or reduction in equipment life. An operative car at AW0 weight shall have the capability of towing an inoperative car at AW0 weight over the whole alignment.

The thermal duty cycle of the friction brake system shall allow an AW3 vehicle to operate indefinitely over the route using only the friction brake system, without wheel temperatures exceeding 600°F, and/or without disc temperatures exceeding 900°F, and without the need to restrict operating speed. This requirement shall be reviewed by the friction brake system supplier; temperature limits may be lowered but not increased.

2.5.4 Acceleration

The acceleration performance specified below shall be met for an AW2-loaded two-car consist on dry, level, tangent track, from a standing start with the master controller in the coast position and brakes released. At weights other than AW2, acceleration may vary proportionately with vehicle weight.

Table 2- 6
DMU Acceleration Requirements

Speed (mph)	Instantaneous Acceleration Rate (mphps)	Time to Reach Speed from Stop (seconds)
0	1.60	0.0
10	1.60	11.0
30	0.70	31.0
50	0.35	75.0
79	0.12	240.0

Vehicle speed effort diagrams and speed over time diagrams shall be provided. CDRL 03

2.5.5 Service Brake Requirement

The DMUs shall be equipped with a friction brake system and a dynamic brake system incorporating the propulsion system components. The service brake rate shall be maintained whether achieved through friction braking or a blend of friction and dynamic brake.

The primary brake shall be a wear free dynamic brake, either electric or hydraulic. In the event of a dynamic brake failure, the friction brakes shall be able to provide the full braking effort.

If electric brakes are provided, the dynamic brake shall be able to provide power to the auxiliaries through regenerative braking. As an option the carbuilder shall investigate the viability of onboard energy storage to recapture most of the brake energy.

The braking system shall produce an average full service braking rate of 2.5 mphps for all vehicle weights up to AW3, for all speeds up to 60 mph, under all weather conditions and with all wheel diameters from new to fully worn wheels, on level, tangent track. The net braking rate may decrease as a function of constant brake power from 2.5 mphps at 60 mph to approximately 2 mphps at 80 mph. The instantaneous brake rate shall not vary from the average rate by more than +/- 10%.

A brake performance diagram including blended braking shall be provided. CDRL 04

2.5.6 Emergency Brake Requirements

The emergency brake rates shall be met under all weather conditions and with all wheel diameters from new to fully worn wheels on level, tangent track. Emergency braking shall not be jerk-limited and shall be irretrievable down to the no-motion detection speed. For emergency brake calculations, the consist may not benefit from train resistance forces.

The emergency brake control system shall be designed in a fail-safe manner. (CDRL 05) It may blend friction and dynamic braking, with friction braking providing the fail-safe default. The specified emergency braking rate shall be achieved in blended and friction-only applications.

The emergency braking system shall produce an average braking rate of 3.0 mphps, after initial buildup, for all vehicle weights up to AW3, for speeds up to 50 mph. Buildup time to this minimum rate shall not exceed one seconds. Above 50 mph, the average emergency brake rate shall be as determined by the characteristics of the friction material, but in not case less than 2.1 mphps at 80 mph. The instantaneous brake rate shall not vary from the average rate by more than +/- 20%.

2.5.7 Load weight

All brake modes shall be load compensated by a load weight signal on a per truck basis. Tractive effort may be load compensated up to maximum engine power.

2.5.8 Minimum Safe Brake Rate

The service and emergency braking system shall be designed and built so that it produces a minimum full service and emergency braking rate of no less than 1.0 mphps on level, tangent track under any single-component failure condition.

2.5.9 Jerk Limits

Changes in propulsion and braking effort shall develop smoothly.

For all brake applications the commanded deceleration shall be reached within 1 second. The rate of change in acceleration during all requested changes in power and brake efforts shall never exceed 3.0 mphps. Jerk limits shall not exceed a tolerance of +/- 10%.

Emergency brake applications shall not be jerk limited.

2.5.10 Mode Change Response Times

Mode change dead times shall not exceed the following:

Table 2- 7
Maximum Mode Change Dead Times

Mode Change	Maximum Response Time
Power to Brake	600 ms
Power to Coast	600 ms
Coast to Brake	300 ms

Mode change dead times from coast to power and brake to power shall be kept as short as possible.

Mode change dead time shall be measured from the time that the applicable control signal changes state until the vehicle acceleration or deceleration reaches 90% of the old commanded value for transitions from Power to Coast or Brake to Coast or 10% of the new commanded value for transitions from Coast to Brake, Power to Brake, Coast to Power, or Brake to Power from a stop.

2.5.11 Spin Slide Control

A system shall be provided to detect and correct wheel spin and slide on each car whether random or synchronous on an individual truck basis, both in acceleration and braking.

Vehicle speed shall be calculated based on all axle speeds in a vehicle.

Efficiency shall be at least 90% in acceleration and in braking for adhesion levels above 5%. Sanders may be used to control adhesion.

2.5.12 Sanding

Sanding shall be applied automatically during correction of major spins and slides. Sanding shall be cancelled at no-motion or if the spin/slide condition is corrected. See Section 13.11 for sanding system details.

2.5.13 No-Motion Detection

A system to detect zero speed shall be provided to be used in conjunction with the door control system for the purpose of preventing the opening of train doors while the train is in motion. The system shall follow fail save principles and detect vehicle speed down to at least 1.5 mph.

2.5.14 Roll Back Prevention

The roll back prevention shall avoid unintended rollback motions on a gradient. If the commanded start up torque is too low, the torque shall be increase by the controls, overriding the command value, to prevent a roll back condition.

2.5.15 Roll Back Protection

The propulsion and braking systems shall prevent the vehicle from rolling in a direction opposite to that selected by the reverser at any point of the alignment.

When moving the MC to a coast position from motoring, the vehicle shall detect and prevent rollback by applying friction brakes upon detection of reverse motion. In either configuration, an AW3 vehicle shall not roll backwards at speeds > 1 mph or more than 20 inches on any specified grade.

2.5.16 Overspeed Protection

Vehicles shall be prevented from exceeding a maximum track speed. The speedometer in the active cab shall give visual and audible warning to the operator if the overspeed limit is reached. If the operator does not reduce speed within a fixed amount of time, consist tractive effort shall be cut and a penalty brake automatically applied. The overspeed limit shall be software selectable and initially set at 83 mph. Overspeed setting shall be limited by hardware or software keys/passwords.

2.5.17 Positive Train Control

Each married pair and/or single car shall be fitted with a Positive Train Control (PTC) system fully compliant with CFR 236 subpart I.. Refer to Section 15, Operational Safety Systems for more details.

2.6 Electromagnetic Emissions

The vehicle shall be designed and constructed so that it does not cause objectionable electrical interference with its own equipment or with any wayside equipment.

Electromagnetic emissions shall meet FCC and ANSI (C63.12.1987) requirements and guidelines.

Vehicles shall be tested to demonstrate compliance with the emission limits defined below, using UMTA-MA-06-0153-85-8. The intent is to ensure these emissions do not adversely affect track signals.

These limits apply to all possible train lengths from two to eight cars in length. The emission limits apply to stationary and moving trains.

2.6.1 Radiated Emissions Limits

The radiated emission limits per train shall not exceed the following values, measured 100 feet from the track centerline. Emission limits are stated as dB microvolts per meter per Megahertz (dBμV/m/MHz) versus log frequency. The "/MHz" refers to the fact that the broadband signal must be analyzed over 1 MHz bandwidths. The term dBμV/m refers to electric field signal strength. Magnetic fields are typically limited to the same values, with the term dBμA/m. Only the electric field values are stated here.

At 14 kHz, the lower limit, a level of 120 dBμV/m/MHz.

A straight line from 120 dBμV/m/MHz at 14 kHz to 75 dBμV/m/MHz at 200 MHz.

A straight line from 75 dBμV/m/MHz at 200 MHz to 90 dBμV/m/MHz at1,000MHz.

A flat line from 90 dBμV/m/MHz from 1,000 MHz to 6,000 MHz.

2.6.2 Inductive Emission Limits

The induced emissions shall not exceed the following limits per car when measured per UMTA-MA-06-0153-85-8 suggested test method.

Frequency (Hz) Most Sensitive Relay Pickup Level (mV) Emission Limit (mV)

Frequency (Hz)	Emission Limit (mV)
20 to 30	55 RMS
50 to 70	55
90 to 110	50
500 to 10 k	20
10 kHz to 20 kHz	10

2.6.3 EMI Testing

See also section.18 Testing

As requirement to ensure EMI, all vehicle electronic systems, which are potential EMI emitters or victims, are to be tested separately by a qualified laboratory. This includes all PTC equipment.

These tests shall include the following specific requirements:

- EC 61000-4-2 Electrostatic discharge Immunity test. Test level 4 is required.
- IEC 61000-4-3 Radiated, radio frequency, electromagnetic field immunity test. This test shall be conducted at a field-strength of 20 V/m. The range from 80 MHz to 6 GHz shall be tested.
- IEC-6100-4-4 Electrical fast transient / burst immunity test. Test Level 4 is required.
- IEC-6100-4-5 Surge immunity test. Test Level 4 is required.
- IEC-6100-4-6 Immunity to conducted disturbances, induced by radio-frequency fields test. Level 3 is required from 150 kHz to 80 MHz.
- Radiated Emissions per FCC part 15, class A levels from 30 MHz to 6 GHz.
- Conducted Emissions per FCC part 15, class A levels from 0.15 MHz to 30 MHz.

For all Immunity testing Performance Criteria A shall be required for all safety critical systems. Performance Criteria B shall be required for all other systems.

2.7 Noise

2.7.1 Interior, Passenger Area

The Contractor is encouraged to provide a quiet ride for the SMART passengers and features to improve noise levels should be proposed. Interior noise in the passenger area shall not exceed the following:

Table 2-8
Interior Noise Limits

Vehicle State	Maximum Noise Level	Notes
Vehicle stationary	70 dBA	Windows and doors closed, all auxiliaries operating simultaneously under normal operating conditions, no passengers.
Vehicle moving	75 dBA	Car operating on any line at any speed except in tunnels

2.7.2 Interior, Cab

The noise level exposure in the cab during normal operation shall not exceed 75 dBA for twelve (12) hours exposure per day. The absolute upper noise level limit, including operation of air horns, bell, or air brake exhaust, is115 dBA per 49 CFR 229.121, but the Contractor will be challenged to minimize the cab noise from these sources during design review..

2.7.3 Exterior, Wayside Noise

The contractor is encouraged to minimize exterior noise levels in keeping with SMART's commitment to minimize impacts on its neighbors. Features to improve this performance should be proposed. Exterior noise, 5 feet above the ground, shall not exceed the levels indicated in the table below. 40CFR201 and 49 CFR 210 or the level specified in Table 2-9 shall be met, which ever is more restrictive.

Table 2-9
DMU Exterior Wayside Noise Levels

Vehicle State	Maximum Noise Level	Notes measured at 25 feet from COT and 5 feet above TOR
Vehicle stationary	75 dBA	All auxiliaries operating simultaneously under normal operating conditions,
Vehicle starting to move	82 dBA	Car starting out of a station stop
Vehicle moving at < 50 mph	83 dBA	Car operating in open country at any speed between 5 and 50 mph in any mode (power, coast, or brake), measured 50 feet from track centerline.
Vehicle moving at 79 mph	86 dBA	Car operating in open country at any speed between 50 and 79 mph in any mode (power, coast, or brake), measured 50 feet from track centerline.

2.8 Shock and Vibration

All vehicle equipment shall be designed to operate without damage or degradation of performance when subjected to vibration and shocks encountered during normal service at all speeds up to 10% above maximum running speed. Carbody-mounted components and equipment shall be designed and tested to withstand continuous vibrations in accordance with IEC 61373, 1999, "Railway Application, Rolling Stock Equipment, Shock and Vibration Tests."

Equipment mounted at any location on the carbody or trucks shall not cause visible or audible vertical or horizontal vibrations anywhere on the vehicle floor, walls, ceiling panels and seat frames, at any specified operating speeds, and under any acceleration or braking condition except emergency braking.

2.8.1 Carbody-mounted Components

- Vibrations up to 0.4 g peak to peak, at frequencies up to 100 Hz.
- Impact loads of 4 g lateral, 4 g vertical, and 8 g longitudinal.

2.8.2 Truck-frame-mounted Components

- Vibrations up to 4 g peak to peak at frequencies up to 100 Hz.
- Impact loads up to 20 g each applied individually on any major axis.

2.8.3 Truck-axle-mounted Components

- Vibrations up to 10 g peak to peak at frequencies up to 100 Hz.
- Impact loads up to 50 g each applied individually on any major axis.

2.9 Ride Quality

The ride quality shall be determined and evaluated according to ISO 2631-1:1997(E). The combined weighted, vertical, lateral and longitudinal rms acceleration values shall not exceed 1.05 ft/sec^2 (0.32 meter/sec^2) over the range of 0.5 Hz to 80 Hz, for load conditions AW0 and AW3 over the full range of operation speed and train acceleration and braking conditions. The car shall be evaluated with new wheels on non-corrugated welded rail

2.10 Reliability

2.10.1 Requirements

The vehicle shall be designed to maximize Mean Time Between Failures (MTBF). Vehicle systems shall meet the Mean Time Between Failure (MTBF) requirements listed below, assuming routine maintenance (scheduled maintenance) is performed as recommended by the Contractor.

Diesel engine requirements are specified in section 10.

The requirements apply to all unscheduled maintenance activities resulting from equipment failures, whether occurring in revenue service or not. The time periods used for determining MTBF compliance will be based on actual car mileage divided by an average schedule speed of 43 mph.

Reliability shall be demonstrated in actual revenue service during the warranty period. Systems which fail to meet reliability goals, after an agreed initial time period, shall be re-designed and retrofitted by the Contractor, at the Contractor's expense, prior to the end of the warranty period.

Table 2-10
MTBF values

System	MTBF(hours per car)
Carbody & Appointments, including seating, windows, cab equipment	4,000
Propulsion, Dynamic Brake & Controls	4,000

including gear case	
Auxiliary Power System	6,000
Friction Braking, including track brake and sanders, and load leveling controls	4,000
Communications and passenger information	7,500
Passenger Doors & Controls,	4,000
Lighting	20,000
Electrical, including the vehicle network and cab controls, and apparatus not included in other systems. Excludes equipment internal to other systems.	5,000
HVAC	6,000
Trucks & Suspension including load leveling suspension elements	10,000

2.10.2 Reliability Demonstration Plan

A reliability demonstration plan shall be developed by the Contractor for approval by SMART prior to the start of revenue service. The plan shall record all vehicle failures during the demonstration period and establish the numerical reliability values for each system.

The plan shall include methods of collecting failure data, analysis of failures, assignment of failures to the appropriate system, corrective action processes, and similar processes.

The plan shall also identify the processes by which corrective actions are applied to systems which fail to meet reliability goals.

2.11 Maintainability

2.11.1 Maintenance Plan

The Contractor shall submit a maintenance program detailing all schedules and activities for the car's corrective and preventive maintenance.

This plan shall be submitted to SMART for review. The plan shall outline each maintenance task, time schedules, recommended tools, personnel, and skill levels required. These recommendations shall be based upon those of the Contractor and of the equipment suppliers. Periodic updates shall be submitted as required.

2.11.2 Maintainability Demonstration

As part of the training program for maintenance personnel, selected servicing, scheduled and preventive maintenance, troubleshooting, change-out of components, corrective maintenance, and use of special tools shall be demonstrated where special emphasis, instruction, or proficiency is needed. Vehicle movement under disabling conditions shall also be demonstrated. The Contractor's demonstration shall verify that durations of these tasks fall within the times established by the Maintenance Plan.

2.11.3 Scheduled And Preventive Maintenance

Scheduled and preventive maintenance are comprised of all tasks necessary to service the vehicle, to defer or prevent failures, and to maximize equipment life.

The scheduled maintenance requirements shall be identified in the preventive maintenance plan (CDRL 07) and be no more frequent than for the following operating miles:

5,000; 25,000; 50,000; 150,000, miles.

Above 150,000 miles the contractor shall suggest at what mileage the first major overhaul is needed and how much time such an overhaul will require. The contractor may suggest other maintenance intervals if they are more suitable for their proposed equipment.

Scheduled activities during the 20,000 mile cycle shall be limited to inspection, filter cleaning or replacement, and replacement of consumables.

2.12 CDRLs

2-1. Car weights and passenger loadings

2-2. Run time simulation Larkspur – Cloverdale

2-3. Vehicle diagrams: Effort vs speed and speed vs time

2-4. Brake performance diagram

2-5. Emergency brake scheme

2-6. Proposed MTTR for major components

2-7. Preventive maintenance plan

3 CARBODY

3.1 Car Structure

3.1.1 General

The vehicles shall be designed and manufactured to be in compliance with 49 CFR 238 requirements applicable to Tier I Passenger Equipment and with all applicable APTA and AAR standards and recommended practices.

The carbody shall meet the latest 49 CFR 238 and APTA SS-C&S-034 “Standard for the Design and Construction of Passenger Railroad Rolling Stock”. The crash energy management (CEM) recommended practice of APTA SS-C&S-034 shall not apply.

The vehicle body shall consist of the roof, the side frames, the underframe, and the end frames. The underframe shall consist of two end underframes, two side sills, body bolsters, and floor beams. Center or intermediate sills may be used in the underframe if necessary.

SMART will consider cab ends covered with fiberglass reinforced plastic panels to provide stylized end contours, provided the overall design meets all structural requirements in this section and all applicable FRA regulations.

Note that CEM features, such as energy absorbing couplers, can be offered and will yield higher technical scores in the evaluation of proposals. If CEM features are offered, they must be offered in addition to FRA compliant features, not in lieu of them.

3.1.2 Analysis

A stress analysis shall be performed showing compliance with the structural requirements of 49 CFR 238 and APTA SS-C&S-034. It shall include, but not be limited to, analysis of the following: carbody, anticlimber, coupler carrier, forward facing end skin, collision posts, corner posts, roof and side rollover strength, side structure and sheathing, truck-to-carbody connection and fuel tank. The analysis shall be submitted for approval prior to the start of construction **[CDRL 3-1].** The truck-to-carbody connection and fuel tank analyses may be submitted separate from the primary stress analysis report. Finite Element Analysis (FEA) software shall be utilized as the main analysis tool.

The stress analysis shall also show compliance with the jacking and hoisting requirements given below.

3.1.3 Equipment Attachment

The attachment of major equipment to the carbody shall meet the requirements of APTA SS-C&S-034, Section 5.7. An analysis that shows compliance with the APTA SS-C&S-034, Section 5.7 requirements shall be submitted for approval **[CDRL 3-2].**

3.1.4 Jacking and Hoisting

The carbody structure shall be designed so that jacks or cradles may be used for lifting the car at the jacking pads. Eight jacking pads per car shall be installed on the side sill in approved locations, to prevent damage to the carbody structure when lifting a car. The bottom of all jack pads shall have a non-skid surface to provide frictional resistance against incidental horizontal loading between the jack pad and jack head.

There shall be no permanent deformation when the car is symmetrically jacked from any combination of pads with the car at AW0 with the trucks attached.

The empty carbody, with trucks attached (AW0), shall be capable of being lifted on the outboard most diagonally opposite jack pads without resultant permanent deformation on any element of the carbody structure.

Lifting lugs capable of being used to right an overturned vehicle shall be provided.

3.1.5 Testing

See Section 18 of this document for test requirements.

3.2 Exterior Equipment

A horn shall be provided at the cab-end of each vehicle, with controls located on the cab console. Horns shall comply with 49 CFR 229.129 and be located on the vehicle roof. They shall be tilted to direct sound and be provided with a shield or deflector to prevent accumulation or packing of debris in the cone. Horn volume shall be adjustable by maintenance personnel.

The cab end of each car shall have headlights and auxiliary lights complying with APTA and 49 CFR 229.125 requirements. The auxiliary lights shall wag (alternately flash) when the horn is sounded.

A snow plow or a snow-plow type pilot shall be provided under the cab end of each vehicle. The lower two inches of the pilot shall be easily replaceable with fasteners. The height of the pilot above top-of-rail, as measured statically on level, tangent track at any weight between AW0 and AW3 and any state of wheel wear, shall meet the requirements of 49 CFR 229.123.

The pilot shall resist a longitudinal load of 50,000 pounds applied at the base of the pilot in line with the rail without permanent deformation. In addition, the pilot shall resist a longitudinal load of 20,000 pounds applied at the base of the pilot located at track centerline without permanent deformation. The pilot shall also resist a lateral load of 30,000 pounds applied at the lower outboard edge of the pilot without permanent deformation. The pilot support structure shall be designed to yield at a maximum of one half the yield load of the associated undercar structure. A stress analysis of the pilot shall be submitted for approval **[CDRL 3-3].**

Cars shall be equipped with red end-of-car marker lights, lighted car number signs, and passenger destination signs. One four-light indicator shall be located on each side of each car to signal brake, door, and PTC status.

Each car shall be equipped with safety appliances fully compliant with 49 CFR 231.

Water-deflecting gutters shall be installed on the roof along the entire side of the car, and over the cab windows and body end doors. The gutter shall discharge at each side of each side doorway, clear of the doorway, adjacent windows, indicator lights, loop steps, and handholds.

3.3 ADA Accessibility

Each vehicle shall provide ADA-compliant access. Vehicle floor and suspension design shall comply with ADA level boarding requirements. If accessibility ramps are required to comply with the car-to-station horizontal or vertical gap requirements, ramps must obey width and slope requirements of the ADA. Access ramps may be manually deployed and stored on the vehicles, and shall not weigh more than 30 pounds.

3.4 Restroom and Service Bar

One ADA compliant restroom shall be provided per married pair. The restroom shall include a fresh water system, a waste retention system, a flushing toilet, a wash basin, one or more mirrors, a trash receptacle, a paper towel dispenser, a toilet paper dispenser, a baby changing table and a ventilation system capable of maintaining a negative pressure within the room.

In addition, one service bar shall be provided per married pair on the non-restroom car. It is preferred that the service bar and the restroom occupy the same space on complementary cars. The service bar shall have a sink with a drain connected to the waste retention system, and space under the counter for a small refrigerator. Lockable latches shall be provided on the service bar doors. The service bar shall be removable so that, if desired in the future, seats can be installed in the space occupied by the service bar. The service bar shall be ADA compliant. The proposed service bar design shall be submitted to SMART for approval **[CDRL 3-4].**

3.5 Floor Height

The vehicle floor shall be nominally level, without interior steps or ramps to change elevation, and shall provide level boarding with high-level station platforms.

Floor height above top of rail shall be adjustable and maintain high-level boarding compatibility through the expected range of vehicle loading and wear.

3.6 Floor Structure and Covering

The floor shall be suitably supported by the car framing to provide a structurally sound and sealed installation which shall not deform permanently under passenger loads up to AW3. The floor deck shall not deflect more than 1/250 of the shortest span between supports, up to a maximum of 0.0625 inches, from a load equal to the sum of dead loads plus a uniformly arranged AW3 passenger load. The installed floor deck shall be flat and level from end to end in each seating level without waviness or buckles. Floor joints shall not be visible or discernible under the floor covering. The floor structure shall be resistant to the effects of water and cleaning fluids.

The floor decking shall be constructed of phenolic composite floor panels, or approved equal. The requirements for the phenolic floor panels are given in Section 17. All exposed edges of the panels, interior holes, interior cutouts and joints between panels shall be machined smooth and free of sharp edges and burrs. The floor material shall be non-vermin supporting and shall not rot, corrode or absorb moisture.

The floor covering shall be of a high performance, resilient, rubber material resistant to damage and wear, and shall be securely bonded to the floor with a thermosetting adhesive recommended by the floor covering manufacture. Joints shall be watertight and minimized. The coefficient of friction of the floor covering shall not be less then 0.060 when tested in accordance with ASTM D 2047. Floor covering designs and materials shall be provided for SMART approval **[CDRL 3 5].**

3.7 Seating Arrangement

Passenger seats shall be arranged in rows of transverse seat pairs, with seats to the left of carbody centerline and seats to the right. Seats should face the nearest exit, with the majority of seats in a front-to-back orientation. Some longitudinal and flip-up seats may be used near interruptions in car interior and wheelchair accommodations.

Seating arrangement must coordinate with vehicle side window spacing.

Seats shall be installed using a track-mounted system. The seats and their mounting system must meet 49 CFR 238.233 and APTA SS-C&S-016-99, “Standard for Seating in Commuter Rail Cars,” including 8g dynamic testing, structural testing for seat strength and structural attachment. A strength analysis report that includes test results shall be submitted to SMART **[CDRL 3-6].** The track shall be of a type that will not permit the seat to slide under the conditions described in 49 CFR 238.233(a)(2).

Seat tracks shall extend through the service bar area to allow for future seating in that area.

3.8 Seats

Seat backs should be tall and supportive with headrests but do not need to recline. Armrests shall be provided on the aisle side and foldable to assist seat egress. Hand holds shall be provided near the seat headrests along the aisle.

Longitudinal and flip-up seats should be significantly similar to the standard passenger seats, but adapted to local design constraints. To maximize the space in wheelchair parking and bicycle parking areas, flip-up seats are preferred in these areas.

Seats shall be a proven design used in rail transit applications. They shall conform to 49 CFR 238.233 and APTA SS-C&S-016-99, "Standard for Seating in Commuter Rail Cars," including 8g dynamic testing, structural testing for seat strength and structural attachment.

Seats shall have modular, replaceable, fabric (90% wool/10% nylon transit grade fabric) covered seat cushions, seatbacks, and headrests. Seat fabric shall conform to 49 CFR 238.103 Appendix B. No footrests or tray tables shall be provided.

3.9 Wheelchair Accommodations

Each vehicle shall have at least two priority wheelchair parking spaces, each located adjacent to an entry door. The passenger seats closest to these locations shall have adequate access to allow a passenger to transfer between a wheelchair and the seat, and shall accommodate companion seating. This arrangement may require a single passenger seat on the opposite side of the aisle.

3.10 Windows and Glazing

All exterior windows in the car shall be certified as meeting the requirements of 49 CFR 223 and 49 CFR 238.221. The certifications shall indicate that all end-facing windows meet the requirements of Type I testing, and that all side-facing windows meet the requirements of Type II testing. It is preferred that glass be used for window glazing. Polycarbonate glazing may be proposed if approved by SMART.

A minimum of four side-facing emergency exit windows shall be provided on each side of the car, meeting the requirements of 49 CFR 238.113. In addition, a minimum of two (one per car side) side-facing emergency access windows shall be provided per car, per 49 CFR 238.114. Dual function windows, meaning a window that is intended to serve as both an emergency window exit and a rescue access window, are permitted, provided they meet both 238.113 and 238.114. Each emergency access/exit window shall provide an unobstructed opening of at least 26 inches horizontally and 24 inches vertically.

Full sized side windows shall be a minimum of 50 inches wide by 40 inches tall.

3.11 Equipment Lockers

Some equipment lockers shall be proposed. Lockers shall be located and arranged to allow easy access by the operator and maintenance personnel. Equipment voltages shall be separated and adequately labeled in compliance with APTA standards.

3.12 Interior Linings and Finishes

The ceiling, side walls, and bulkhead walls shall be finished with integrally colored melamine, fiberglass reinforced plastic, or similar approved materials and color, applied and fastened in a manner to permit ready removal for maintenance. Where fiberglass reinforced plastic is used, it shall be Tedlar covered using the in-mold process or as approved. Linings shall be of sufficient strength and adequately supported to resist damage. For each of the interior finishes the Contractor shall submit a repair procedure to SMART for approval **[CDRL 3-7].**

End walls, bulkheads, windscreens, and other partitions shall be solid core or aluminum honeycomb laminated melamine. Side wall window masks shall be Tedlar covered fiberglass or aluminum. The Tedlar shall be applied using the in-mold process or as approved. The masks shall be retained by elastomeric glazing strips around the windows. Edge radii design of the window masks, as well as the installation procedures, shall prevent stress cracking.

Supporting technical datasheets for liners, masks and associated trim pieces, bulkheads, end walls, windscreens, and other vehicle surfaces shall be provided by the contractor. The supporting technical data sheets for each material shall be submitted to SMART for approval **[CDRL 3-8]**

3.13 Stanchions and Windscreens

All stanchions, handrails and grab rails shall meet the requirements of ADA, 49 CFR 38, 49 CFR 231, 49 CFR 238, and APTA Standard for Attachment Strength of Interior Fittings for Passenger Rail Equipment APTA SS-C&S-006-98.

Circumferential brush finished, 120 grit, stainless steel stanchions, including tubing, fasteners, and fittings shall be provided in the area of the side doors, and in other areas where passengers are likely to accumulate. Suitable handholds shall be installed on both sides of each side door opening to assist passengers boarding or alighting from the car. Stanchions of suitable strength and rigidity shall be provided with an outside diameter of 1.25 to 1.5 inches.

Windscreens shall be provided at the side of each side door opening, extending from approximately 6 inches above the floor to ceiling and projecting sufficiently into the car to provide the desired protection while not interfering with wheelchair or bicycle movement. Windscreen glass shall be minimum 3/8 inch thick tempered and laminated safety glass with dark tint on the lover level to provide privacy. Windscreens shall include integral stanchions. Details of the design and assembly of stanchions, handholds, handrails and windscreens shall be submitted to SMART for approval **[CDRL 3-9].**

3.14 Special Requirements

3.14.1 Bicycle Stowage

At least four bicycle stowage locations shall be provided in each car. These locations may use the same floor space as the wheelchair parking locations, with priority given to wheelchairs in cases of conflict. Stowage locations shall provide positive restraint of the bicycle, compliant with the carbody impact, shock, and vibration criteria and compliant with 49 CFR 238.233, and shall not interfere with passenger ingress or egress

3.14.2 Luggage Stowage

Cars shall be equipped with luggage bins located above the passenger seats. Luggage bins shall be compliant with 49 CFR 238.233.

3.14.3 Work Tables

Four to eight work tables shall be provided at facing seat locations. Work tables shall be designed in such a manner to provide an aesthetically pleasing, cleanable, stable work surface for writing, retaining computers or food. The edge treatment shall be resilient material and provide a marine edge to retain fluid spills. The work table shall comply with all aspects of 49 CFR 238.233 and be tested in conjunction with the seating per APTA SS-C&S-016-99, Rev. 1 or later. Energy absorption features shall be built into the work table such that the Human Injury Limits for 50^{th} percentile male ATD are not exceeded during dynamic sled testing as per APTA SS-C&S-016-99, Rev. 1, Section 5.2.1 modified for test seating with a work table. The table profile shall consider entrance and exit to the window seats. The design, location and mounting of the work tables shall be submitted to SMART for approval **[CDRL 3-10].**

3.15 CDRL

The following submittals are required:

3-1 Carbody stress analysis

3-2 Equipment attachment analysis

3-3 Pilot stress analysis

3-4 Service bar design

3-5 Floor covering samples

3-6 Seat strength analysis

3-7 Interior finish repair procedures

3-8 Interior material data sheets

3-9 Stanchion/windscreen design

3-10 Work table design

4 COUPLER, DRAFT GEAR AND TOW PROVISIONS

4.1 Coupler and Draft Gear

4.1.1 Mechanical

The coupler system shall be service proven and shall meet the requirements of 49 CFR 229.61, 238.205, and 238.207, as well as all applicable APTA and AAR Standards and Recommended Practices. The cab ends of the cars shall have an automatic coupler system that will make all mechanical, pneumatic, and electrical trainline connections when mated. The non-cab ends of the cars shall have either an automatic coupler or a semi-permanent drawbar. If a semi-permanent drawbar is used, electrical and pneumatic connections shall use connectors that allow the two halves of a married pair to be separated in a shop environment. The proposed coupler system design shall be submitted to SMART prior to car construction **[CDRL 4-1].**

The coupler connections shall permit operation of up to four vehicles in a train under normal conditions through electric and pneumatic trainlines. Coupler controls shall be located in each operator's cab and outside the vehicle near each automatic coupler.

The coupler and draft gear shall have the strength needed to allow, under emergency conditions, a train of four vehicles with an AW3 passenger load to push or pull an inoperable train of up to four vehicles with an AW3 passenger load, without damage to the coupler or its anchorage.

Each coupler shall have a carrier that maintains nominal coupler height while allowing vertical dynamic motion. Each coupler shall have an automatic horizontal centering device that aligns an unloaded coupler to carbody centerline. The coupler carrier and centering device shall be adjustable to allow maintenance personnel to correct for wheel, truck, suspension, and carbody wear. The coupler location shall be maintained within 1-1/2 inches vertically and 1-1/2 inches horizontally of its nominal position on level, tangent track with new wheels under all static conditions from AW0 to AW3. Coupler adjustment shall not be required more frequently than 92-day intervals.

Coupler gathering range shall be a minimum of 3-3/4 inches of misalignment between opposing coupler centerlines. The coupler gathering range shall be sufficient for two cars to automatically couple on tangent track when each coupler is maintained within the above stated tolerance. Likewise, two cars shall be able to couple on a 12.5 degree horizontal curve.

4.1.2 Electrical

Each coupler assembly shall be provided with electrical coupler heads capable of making all necessary low voltage electrical connections between adjacent cars to permit normal control of all cars in a train from the controlling car.

Coupler electrical connections shall transmit trainline control signals, as defined by the Contractor. The coupler electrical connections shall allow transmitting battery level signals, communications and train bus signals (if applicable).

Contacts for high energy (battery level) signals shall be silver plated. Contacts for low energy (train bus, etc) signals shall be gold plated.

Contacts and wirings shall be dimensioned to operate/power a 300-foot consist from one end.

4.1.3 Pneumatic

The coupler shall be capable of making all necessary connections for trainlining the main reservoirs and the control pressure (brake pipe) if applicable.

To prevent debris from entering the pneumatic trainlines, a tappet valve shall be provided in the face of the coupler for each pneumatic trainline. The tappet valve shall automatically open upon mechanical coupling and automatically close upon mechanical uncoupling.

4.2 Tow Provisions

The following provisions shall be provided to permit rescue by a standard locomotive.

4.2.1 Coupler Adapter

Each car shall be equipped with one coupler adapter to allow the commuter rail vehicles to be connected to a conventional AAR type-E, F, or H coupler. The removable adapter shall have a maximum weight of 65 pounds and be normally stored on the F-end pilot. It shall be able to withstand 100,000 pounds in buff or draft without permanent deformation. The operator shall be able to manually install or remove the adapter alone and without tools. The adapter is anticipated to be used only during emergency or rescue situations.

4.2.2 Pneumatic Connections

Provision shall be made to permit a standard locomotive to connect to the control pressure (brake pipe) pneumatic trainline when the coupler adapter is used to move the commuter rail vehicle. In addition to the automatic coupler pneumatic connections, the control pressure (brake pipe) pneumatic trainlines shall be piped to a location adjacent to the coupler with cut-out cocks and fittings to allow application of a standard brake pipe hose with glad hand. The geometry shall allow coupling to a locomotive brake pipe hose. One hose with fittings shall be provided with each commuter rail vehicle.

4.2.3 480 Volt Receptacles

Receptacles and appropriate electrical switchgear shall be provided at each end of the commuter rail vehicle to permit 480 volt three phase auxiliary power trainlined between cars. This will not be the normal operating mode, but will be used in emergency situations to permit a car with a failed auxiliary power supply to be powered from an adjacent car with an operating auxiliary power supply.

The receptacles and cables shall comply with APTA RP-E-018-99 “Recommended Practice for 480 VAC Head End Power Jumper and Receptacle Hardware”. One portable jumper cable assembly shall be provided for each commuter rail vehicle.

4.3 CDRL

The following submittals are required:

4-1 Coupler system design

5. OPERATOR'S CAB

5.1 General

An operator's cab shall be located at the F/E of each car of the married pair.

The full width operator's cab shall provide control devices for operating the train in an ergonomic, climate-controlled environment. The cab shall provide a desk-like console for the throttle and brake controls. An integrated (master) controller for throttle and braking is preferred. The operator's seat shall swivel to assist access. It shall have vertical and longitudinal adjustments to accommodate operator's ranging between 5th and 95th percentile US males and females, as defined by Military Standard MIL-STD-1472, latest revision. It shall also provide vertical suspension and damping. Seat adjustments shall be electronic or manual.

The relationship between the Operator and the windshield shall be designed to optimize the field of view while minimizing the windshield area. The cab layout shall provide the Operator with an effective field of view to the right and left of the direction of travel. Obstructions to the field of view shall be minimized.

The interior of the cab shall present a clean, pleasing appearance and shall be free of sharp edges and protrusions.

Space shall be allocated in the cab area for the Operator's personal effects.

Outside mirrors shall be provided on each side of the vehicle, to allow rearward sight down the side of the consist while seating in the operators seat. Mirrors shall be electronically heated and independently adjustable. The mirrors shall not interfere with the clearance diagrams referenced in Section 2. As an option rear facing side cameras may be proposed to SMART for review and approval.

Any pneumatic component mounted in the cab or cab area shall be vent outside of cab or passenger compartment.

The cab door shall be equipped with a panic bar for emergency egress from the cab to the vestibule, a window, and a privacy roller shade.

The operator's side-facing windows shall allow easy opening and closing. It shall meet the requirements of 49 CFR 238.113 for emergency exit windows and shall provide an unobstructed opening of at least 26 inches horizontally and 24 inches vertically. These windows shall not be assumed accessible to passengers and shall not count toward the emergency exit window

Each cab shall be equipped with at least one forward facing camera. The recorded field of view shall be a 180-degree arc in front of the vehicle. See Section 14 for more details.

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5.2 Cab Design

The cab shall be designed so that all devices and equipment are integrated (built-in and flush-mounted) into the console, walls, ceiling, or floor. The design shall group controls and instruments for function, maintenance, and servicing. All equipment shall be attached with machine screws to either tapping plates or captive nuts.

Primary console features shall be positioned to be accessible and functional from the Operator's seated position with all primary operating controls and displays mounted within the Operator's console desk. Normal operation shall not require awkward or unnatural positioning, extension, or excessive movement by the Operator.

Secondary controls, switches, and features, not used for train operation, shall be placed on panels more remote but accessible to the Operator. Electrical and control enclosures shall be designed to preclude the intrusion of water and dust. The cab must be designed and constructed such that it can be cleaned regularly without damage to electronic equipment

To the extent possible, indicator lights shall be grouped together in a panel with a single push-to-test button. The use of quick disconnects shall be maximized to facilitate removal and replacement of components.

The Car Builder shall submit drawings of the cab identifying all controls and ergonomic considerations for review and approval by SMART **[CDRL 5-1].**

5.3 Primary Control Console

At a minimum, the following features shall be provided at the primary control console:

Description	Indicator Light	Switch	Audible Alarm
Master Controller:			
Key Switch	-	Rotary	-
Reverser	-	Rotary	-
Power/Brake Lever	-	-	-
Central Diagnostics Panel	-	-	-
Train Operators Display (including speedometer)	-	-	-
ATC/PTC/Alerter Acknowledging Switch	-	Momentary	-
Horn Operating Handle	-	Momentary Pneumatic	-
ATC/PTC Display Unit	multiple	-	-
Communication Buzzer	-	Momentary	Yes
Radio Control Head	Yes	-	-
Analog Brake Pressure gauges			

5.4 Operator's Main Switch Panel

At a minimum, the following features shall be located on the Operator's Main Switch Panel located above the console on the right side of the windshield:

Description	Indicator Light	Switch	Audible Alarm
Charging	-	Momentary	-
Gauges Lights (Min. – Max. Dimmer)	-	Rotary	-
Headlight/Auxiliary/ Light Switch (Off – Dim – Bright-- Flashing) (section 9.13.1)	-	Rotary	-
Cab Heat (Off – Fan Only – Half Heat – Full Heat)	Yes	Toggle	-
Fresh Air Intake (Normal – Closed)	-	Toggle	-
Windshield Wiper/Washer (Int., Off, Low, High, (Push To Wash)	-	Rotary/ Momentary	-
Compartment Ceiling Lights (Off – On)	-	Toggle*	-
Cab Gimbal Light (Off, Min. – Max.)	-	Rotary	-
Uncoupling Key Switch (Off – On)	-	Rotary	-
Engine Start/Run/Stop Switch		Toggle	
Generator Field Switch		Momentary	
Emergency Fuel Cutoff Switch		Momentary#	
Engine Fire Detection Light	-	-	-
Fire System Override Switch		Momentary#	
Load Meters	-	-	-
Lamp Test Button For All Indicating Lights	-	Momentary	-
Dimmer For All Indicating Lights, Gauge Lights, And Tod	-	Rotary	-
Door Controls	Yes	Momentary	
Cab HVAC		Toggle	

5.5 Operator's Bypass Switch Panel

At a minimum, the following features shall be located on the Operator's Bypass Switch Panel located above the console on the left side of the windshield:

Description	Indicator Light	Switch	Audible Alarm
Brake Release Trainline	Green/Flash Green	-	-
Door Closed(Traction Interlock)/ Bypass Indicator	Green/ Flash Green	-	-
Door Bypass		Toggle*#	-
Power Knock Out (PKO) Bypass	-	Momentary	-
Positive Train Control		Toggle*#	
Brakes Applied	Amber	-	-

Legend: * Sealed # Guarded switch

5.6 Parking Brake Controls

A means to apply and release the spring applied parking brake shall be included in the operators cab area. The device shall be secured in a locked panel to prevent an inadvertent activation or deactivation

5.7 CDRL's

5-1 Cab Layout depicting all features required in Section 5.

6 PASSENGER DOORS

6.1 General

Each car shall have four door openings, two on each side of the car, directly across from each other, located just inboard of the trucks. Doors shall be of the sliding pocket or plug type, covering the entire height of the door opening.

Two center doors instead of four ¼ doors may be proposed if the door leaves are operated independently and comply with the requirements below on a per door leaf basis. Such a door arrangement will need SMART approval.

The design, operation, installation, arrangement, and signage of the door system shall comply with APTA RP-C&S-012-99 and 49 CFR 27, 37, 38, and 238.

Each doorway shall include two door panels, which slide in opposite directions, parallel to the side of the car. The Clear width of all doorways shall be at least 51 inches. Doorway height, measured from the vehicle floor to the bottom of the door header, shall be a minimum of 78 inches. Panels shall not protrude more than 3 inches from the vehicle side during any portion of the opening or closing cycle.

Door opening and closing shall be interlocked with the no-motion circuits. All doors shall be controlled from trainline signals issued by the operator. Trainlined door control signals shall allow the operator to release, open and close all doors in a consist. If the doors are released, passengers shall be able to control doors from pushbuttons located on or adjacent to the door panels, when the pushbuttons are enabled by the operator, and the no-motion trainline is energized.

The door panels, door mechanisms, door controls, and equipment shall be based on, nearly identical to, a service proven design, meeting the requirements of section 2. The door controls and all door equipment shall be interchangeable, from one location to another, and car to car.

No single point failure of the door system shall cause,

- Any door to unlock or open
- A door open command to be transmitted or responded to when the train is in motion
- A door closed indication to be transmitted when any door is unlocked or open
- A traction interlock OK status when any door is unlocked or opened
- A door closed indication to be transmitted when an unlock or opening command is stored anywhere in the system

Details of the design, hardware, relays, control circuits, software, diagnostics, usage, arrangement and location of the Door System shall be submitted to SMART for review and approval **[CDRL 6 – 1].**

6.2 Door Pockets

Door pockets shall be designed to provide proper door movement within the pocket and adequate drainage of snow, dirt, and/or debris that could normally build up inside the pocket. The gap between the door and the pocket shall ensure that a passenger's hand or fingers cannot be placed between the panel and the pocket walls. Door pocket wiring shall be installed in rigid conduit. Wire bundles or flexible conduit will not be acceptable.

6.3 Door Panels and Seals

Heavy-duty brush type seals on the interior and exterior of the door frame shall fully contact the door-mounted seals. The seals shall exclude moisture and dirt from the door pocket and the car interior. The brush seals shall be located within ¼-inch of the face of the door panel to provide a tactile warning to passengers that may have their hands against the door panel prior to opening. Location of the brush seals shall not cause excessive air leakage or condensation around the door.

6.4 Door Functional Requirements

Door motion shall be smooth and free of shock and impact. Cushioning shall be provided at the end of travel of the door in both the opening and closing directions. In the event of a loss of local control power, the doors shall remain in the last commanded position during absence of control power and when power is restored.

The delay time from receipt of a door command signal by the door controls to the first motion of a door panel shall not exceed 0.15s. The operating time of any door, from time of first motion to the point of completion, including cushioning, shall be 2.5s to open and 3.0s to close, ±0.2s. Operating times shall be adjustable by software changes.

A mechanical door lock function shall positively retain the doors in the closed position, even during loss of power. The lock shall automatically engage when both door panels reach the closed position. A manual release shall be provided at each doorway, to release the lock and allow the door panels to be manually opened during an emergency.

Electrical position-sensing switches shall be provided to detect when each door panel is fully closed and locked.

Two independent trainline signals shall be required to open the doors, Release signal and Door Open signal. To permit passenger opening of the doors using local pushbuttons, only the Release signal shall be required. Both signals and the passenger pushbuttons shall be interlocked with the no-motion circuitry. The

door control system shall be considered a train safety system and shall conform to the safety requirements of section 16.

6.5 Side Door Operator

Each doorway shall be provided with one electrically powered door operator, powered from the low voltage dc system. The left and right door panels shall move simultaneously, through a shaft or linkage arrangement. No linkage shall be provided for independently operated center doors. Operator adjustments shall not be required as part of routine maintenance.

The operator shall be located in the transom area above the doorway, or other location suitable to the door arrangement. The operator shall not be located below the floor level. The shaft or linkage shall be concealed, except as needed for the sliding mechanism, such that it is not directly visible when the door is opening and closing, or when the door is in the fully closed position. Access to the door operator shall be by opening a cover or removing an access panel, without the need to move or disconnect other equipment. Sufficient clearance and access space shall be provided to maintain all components, and to remove the assemblies as complete units.

The door operator shall be capable of the following, without affecting the reliability and service life of the operator:

- Operating over the voltage range specified in Section 9.
- Opening and closing the doors at the specified performance levels with the most unfavorable, ambient wind, and car pressurization conditions
- Withstand stall current indefinitely, or alternately: detect condition, remove power, and reset automatically when door controls are cycled.

6.6 Door Operator Control Panel

Each door operator shall be controlled by a microprocessor-based control system, located in the transom header area. The system shall control all aspects of door motion, including: opening speed, closing speed, closing forces, detection of stalls, accelerations, decelerations, and door close time delays. The controller shall read and respond to trainline / local commands, monitor door status, and provide system diagnostics.

Refer to Section 11 for electronic controls and software systems requirements.

6.6.1 Diagnostics and Adjustments

The status of the door system shall be available via, diagnostics system integral to the door controller software and the MDS system. Refer to Section 11 for MDS requirements.

The diagnostic system shall monitor all critical internal functions, external inputs, and the mechanical door systems, including door open, closed, and lock status.

Actual door performance, such as door speeds on opening and closing, shall also be monitored.

Each door controller shall be linked to the train's data network. Alternatively, each door may be connected in a local network, with a single connection point to the train's data network. In either configuration, status and diagnostic information from each door shall be available at a single common location, and the train MDS system.

Failure of the network links shall have no effect on door operation, and network failures shall be announced at the diagnostics port and the MDS system.

Diagnostics from each door controller shall also be available either a separate connector at the controller, or the network connector itself. The door controller shall also permit adjustments of all operating variables, such as door speeds and timing, via laptop computer. These adjustments shall be available locally, or via the vehicle's network. There shall be a separate location for system wear.

The mounting of all sensors and switches shall be such that no readjustment shall be necessary when any given sensor or switch is replaced.

The diagnostics and adjustment capabilities of the door system shall be reviewed and approved by SMART **[Included in CDRL 6 – 1].**

6.7 Door Obstruction Detection

The door system shall automatically detect obstructions, prevent a door from becoming entrapped, and limit the forces imparted to a person in the doorway; it shall be reviewed and approved by SMART **[Included in CDRL 6 – 1]**.

6.7.1 Operational Requirements

An electric sensitive edge shall be incorporated within the leading edge of each door panel. In addition, the door control equipment shall detect restrictions in door motion via current sensing, speed vs. time tracking, or other approved methods.

Upon detection of an obstruction, the door panels in the affected doorway shall immediately decelerate, open and remain open for a preset period, controlled by an adjustable time delay circuit, adjustable in software from zero to 10 s initially set to 2 seconds. The door panels shall then again attempt to close. If the obstruction is no longer detected, the doors shall close and lock.

If the obstruction is still detected, the door panels shall continue to recycle for a pre-set number of times. If the recycle count is exceeded, the doors shall remain in the open position until reset by the operator. The recycle count shall be settable in software by the user, and initially set to 5.

If an open command is issued at any time, it shall override and reset the obstruction detection circuitry.

6.7.2 Sensitivity Requirements

The obstruction detection system shall detect any force opposing door motion in excess of 50 N.

In addition, the sensitivity of the obstruction detection system, for each panel separately, shall be as follows:

- It shall detect a flat bar, 10 mm wide and 75 mm high, held rigidly between and perpendicular to the door panel, as a hand might be held to stop the doors. This sensitivity shall be required everywhere along the length of the panel except the uppermost 75 mm of the nosing seal.

- It shall detect a cylindrical object, 20 mm in diameter, held rigidly between and perpendicular to the door panels at all locations along the length of the door nosing seal, except the uppermost 75 mm and lowermost 25 mm of the seal.

6.8 Control Switches and Pushbuttons

The doors shall be controlled from the crew switches, the cab door control pushbuttons, and the passenger pushbuttons. Switches and pushbuttons used for these controls shall be of heavy-duty, industrial type, suitable for frequent use.

6.8.1 Cab Console Switches

Each cab shall include pushbutton switches for control of doors by the operator. The switches shall be arranged logically and physically separated left / right to reduce the possibility of inadvertent door operation.

6.8.2 Crew Switches

Each side door shall be provided with weatherproof electrical rotary switches operated by the crew key. Switches shall be located inside and outside the vehicle, a total of two per doorway. The outside switches shall be located beyond the open position of the door.

The crew switch and related circuits shall have applied power only when both cabs in the vehicle are keyed Off. The switch and the adjacent door operator shall be arranged so that they can function independently of the cab console controls.

The crew switch and associated circuits shall be considered a safety circuit, and shall meet the requirements of Section16.

6.8.3 Passenger Pushbuttons

Each doorway shall be provided with illuminated pushbuttons on the inside and outside of the vehicle to permit passengers to open the doors. The pushbuttons shall flash with the audible door closing warning, per section 1.6.12.2 – Door Warning Indicators.

The door pushbuttons and surrounding bezels, shall be color-coded with approved colors. The switch names shall be molded into the switch in raised lettering, dimensioned to permit sensing by a visually impaired person. The pushbutton illumination shall be Green when active, and dark or Red when inactive.

The sizes, locations, colors, graphics, and other features of the pushbuttons shall be approved by SMART **[CDRL 6 – 2].**

6.9 Emergency Door Release

Emergency operation of the door system shall comply with the requirements of APTA RP-C&S- 012-99 and 49 CFR 238.235.

An Interior and exterior manual (Emergency) door release mechanism shall be provided for each side door, permitting the doors to be opened locally, without the use of electric power. When the mechanism is activated the following shall occur:

- Interrupt door status interlock causing propulsion power to be removed, and an irretrievable Full Service Brake applied.
- Illuminate “Passenger Emergency” on the operator indicator panel in each cab, in the train, and sound an audible alert in each cab.
- Open the door a sufficient amount, such that, the train crew, emergency personnel and / or passengers clearly know that the door has been released and is open.

Signage shall be placed adjacent to the Emergency Door Release, providing instructions for its use, as required by FRA and APTA standards.

Details of the access, operation and design of the emergency door release shall be submitted to SMART for review and approval **[CDRL 6 – 3].**

6.10 Interlock Requirements

6.10.1 No-motion Interlock

All door controls shall be electrically interlocked, in a safe manner, with the no-motion circuitry, described in section 1.2.5.13, so that the doors can be powered open only when the train is stopped. When motion is detected, a close command shall be issued to all doors in a train, the doors shall not respond to any open commands until no-motion is detected.

Power to door opening circuits for the door operators, controls, and door motors, shall be switched with non-welding critical circuit relays, as approved, controlled by the no-motion trainline. When motion is detected, both the positive and negative feeds for these circuits shall be disconnected from the low voltage power. All diagnostic and fault monitoring, logging, shall remain active when the train is in motion.

6.10.2 Door Status (Open) Interlock

An electric loop circuit shall be provided to monitor the door panel position for each side of the train, consisting of electrical position sensing switches. The switches shall detect that each panel is fully closed. A separate set of switches shall be provided to detect that each panel is properly locked. The switches shall positively and directly detect the actual panel and lock positions

For each side of the car, the switches shall be placed in series, activating a summary Door Status critical circuit relay, as approved, when all door panels are properly closed and locked. If any one of the closed or locked switches is not made up, the door status relay shall not be energized, the cab Door Open light for that side of the train shall be illuminated, the interior and exterior door light for that doorway shall be illuminated, propulsion power removed, and Full Service Brake (FSB) shall be applied.

If an attempt is made to apply power with any door panel not closed and locked, the master controller shall have to be placed in the FSB position after the summary door status relays are energized before the brakes can be released and power applied.

No single point failure in the loop circuit shall cause a false doors closed and locked signal. Where failures in the loop circuit are not self-annunciating, they shall not lead to a false doors closed and locked signal, from the door interlock circuit, or in association with other single point failures.

6.11 Door Bypass Devices

Bypass devices shall be provided to circumvent specific door system faults, so that the train can, continue in revenue service, be removed from revenue service and returned to the maintenance facility, or moved to clear the line.

6.11.1 Door Interlock Bypass

A sealed door interlock bypass feature shall be provided in each cab, active only when the associated cab is powered, permitting movement of the train under emergency conditions. The activation of the bypass switch shall be recorded and logged by the Event Recorded.

The door interlock bypass shall bypass the door status interlock so that the brakes can be released and power applied. It shall not provide a false doors closed indication.

6.11.2 Door Cutout

A manual door cutout device shall be provided at each door operator, and shall be arranged to perform the following functions, in the event that a defective door must be cutout.

- Disconnect the door motor
- Bypass door-closed and door-lock interlocks for that door
- Assure that the door remains closed by mechanical restraint; operation of the Emergency Door Release shall disable or release the restraint, allowing the door to be opened
- Deactivate the local passenger pushbutton light, activate the trainline door cutout indicator, and activate the door out of service indicators

The cutout device shall be located in the transom area above the doorway.

6.12 Annunciators

6.12.1 Door Open and Release Indications

The following LED cluster indicator status lights shall be provided as part of the Operator's console for left and right door control.

- Red – Left/Right Door Open pushbutton
- Yellow – Left/Right door Release pushbutton
- Green – Left/Right Door Close pushbutton

Each doorway shall have two yellow LED Door Open indicator status lights, one interior, mounted underside of the door transom above each doorway, and one exterior, mounted above the center of the doorway. When either panel in the adjacent doorway is mechanically unlocked, open, or both, the indicators shall be illuminated.

6.12.2 Door Warning Indicators

An audible warning indicating that the doors are closing shall be provided, independently for each doorway, 2 seconds prior to doors closing (adjustable 0 – 2 s). The warning shall be, a pleasant two-tone chime, generated electronically by the local door control system, audible inside and outside the train. The tone and intensity of the warning shall be reviewed and approved by SMART. **[Include in CDRL 6 – 4]**

An Amber visual door closing warning, and the passenger door open pushbuttons shall flash, with the audible warning, on both sides of each doorway. The visual indicators shall be located on the side of the door frame, visible inside and outside the car regardless of door position. If the visual door warning cannot

be seen from outside the car with the doors closed, a duplicate weatherproof device shall be provided on the outside of each doorway. The indicator shall be reviewed and approved by SMART. **[Include in CDRL 6 – 4]**

6.13 Trainlines

All door control and status trainlines shall be configured in a completely separate left/right side of car configuration.

6.14 CDRL

The following design submittals are required:

6. - 1 Door System design package
6. - 2 Passenger Pushbuttons
6. - 3 Emergency Door Release
6. - 4 Door Warning indication

7 HEATING, VENTILATION AND AIR CONDITIONING (HVAC)

7.1 General Requirements and Features

Each Single Car (car) shall include two separate, unitized, roof-mounted HVAC units that shall be capable of maintaining an interior temperature between 68°F and 76°F (20-24.5°C) and relative humidity not to exceed 60% under all ambient conditions with any passenger loading up to the Design Criteria as specified below.

All HVAC units shall be identical and interchangeable on the same car and between all cars in this Contract. Equipment design and installation shall provide full accessibility for maintenance, troubleshooting, and minor repairs without interference with other systems. Each of the entire HVAC units shall be removable, with the use of an overhead crane, without any disconnections of refrigeration piping. Time required to remove and replace one unit shall not exceed two (2) man-hours.

Each HVAC unit shall have its own controls, including a complete set of temperature sensors and microprocessor logic controllers, and it shall be able to function independently in the event of failure of the other unit on the same car. A communication link shall be provided between the units on the same car, such that when both units and their controls are operational they should operate in the same or adjacent modes in the control scheme. In the event of one control unit failure, the other functional controller shall operate both HVAC units in the same control mode.

Heating shall be provided by the overhead heaters supplied as part of the unitized HVAC equipment, and by the floor heaters.

Air ducting shall be arranged such that each HVAC unit will provide its portion of the conditioned air to the entire vehicle in case of the other unit failure, with the possible exception of the area immediately below the failed unit.

Each car shall have a layover heating and cooling mode operated from 480VAC, 3-phase, 60 Hz wayside power, which is capable of maintaining vehicle conditions during extended layovers without passengers, as described in Section 7.6.4. A switch shall be provided in the cab to enable the layover operation.

All system components shall be supported by design and test data that is adequate and acceptable to SMART that will demonstrate compliance with the specified requirements. The HVAC system shall be designed and constructed to operate under the shock and vibration conditions specified in Section 2. The HVAC system shall not impose vibrations greater than those specified in Section 2 to the carbody in any mode of operation. Interior and exterior sound levels shall meet the requirements of Section 2.

HVAC system design shall meet all applicable safety requirements listed in UL 1995 Standard (latest revision), for both cooling and heating equipment unless otherwise specified herein.

Details of the system capacity and performance calculations, design, arrangement, installation, and operation of the HVAC system shall be submitted to SMART for review and approval **[CDRL 7-01]**

7.2 Design Criteria

7.2.1 Design Thermal Loads

The HVAC system design parameters are specified in the following table:

Table 7-1
Design Criteria

Ambient Temperature (Summer)	95oF (35°C) Dry Bulb (DB), 67o F (19.5°C) Wet Bulb (WB)
Ambient Temperature (Winter)	30oF (-1°C) Dry Bulb
Passenger Load	AW2, with 450 Btu/hr, 55% SHR, per person
Interior Design Conditions	75oF (24°C) DB and 55% RH (Cooling) 70oF (21°C) DB (Heating)
Fresh Air	6 cfm (2.8 l/s), minimum, per passenger at AW2 passenger load
Carbody Heat Transmission	In accordance with the Contractor's carbody and insulation design to meet the requirements of this Specification
Lighting Load	Total wattage of interior lights considering ballast efficiency
Solar Load	In accordance with ASHRAE data and calculation methods
Miscellaneous Equipment	In accordance with Contractor's design data and shall include blowers and other equipment

7.2.2 Interior Temperatures

A comfort control system shall be designed to automatically provide the specified control of car interior temperatures with any ambient temperature from 30°F (-1°C) to 95°F (35°C) at the specified wet bulb conditions, with or without or partially without variable internal heat loads such as passengers, motors, lights and solar gain, at the nominal applied voltages. The cooling system shall also remain in operation, at reduced capacity if necessary, should the design cooling conditions be exceeded.

The average temperature throughout the passenger area shall be maintained at the following temperatures for the respective ambient temperatures:

Table 7-2

Interior Temperature Conditions

Exterior Ambient	Interior Ambient
Less than 60°F (15.5°C)	67°F – 70°F (19°C to 21°C)
60°F to 95°F (15.5°C to 35°C)	72°F – 76°F (22°C to 24.5°C)
95°F to 105°F (35°C to 40.5°C)	Not higher than 20°F (11°C) below the ambient dry bulb
Above 105°F (40.5°C)	As the system will provide

The interior relative humidity shall not exceed 60% at any time when the HVAC system is operating in the cooling mode.

The temperature in the cab, with the side window closed and the operating compartment heater turned to "OFF", shall conform to the requirements for interior car temperature when air conditioning is in use.

The following variations in interior car temperatures are the maximum that shall be allowed throughout the entire car, simultaneously:

- At any given time, except during pull-down and warm-up, among all points in the same horizontal plane from one end of the car to the other should not be more than 4°F (2°C).

- At any given time, except during pull-down and warm-up, between any point at 43 inches (1.1 m) above the floor in the seating areas or 67 inches (1.7 m) in the standing areas and the corresponding point 4 inches (0.1 m) above the floor in a vertical plane should not be more than 4°F (2°C).

- At any given point in the car, and in the entrance ways and at least 12 inches (0.3 m) from the ceiling and 4 inches (0.1 m) from the floor and walls over a period of time should not be more than 5°F (2.5°C).

- The average car temperature shall recover within 2°F (1°C) of the required interior car conditions within 2 minutes maximum following a 30 second door opening. This requirement shall be met during 1 hour of continuous door cycling of 30 seconds open and 2.5 minutes closed at design conditions in both air conditioning and heating modes.

7.3 Heating

7.3.1 Heating Arrangement

The cars shall be electrically heated by a thermostatically controlled system, using a combination of the overhead heat from the heater elements, supplied as part of the unitized HVAC system, and the floor level sidewall heaters evenly distributed throughout the car.

7.3.2 Heating Capacity

The overhead heater coils shall have sufficient capacity to heat the total input of fresh air from 30°F (-1°C) to 68°F (20°C) at 480 VAC.

The floor heat shall have sufficient capacity to heat the car interior from 30ºF (-1°C) to 68ºF (20°C) with the ventilating fans and overhead heat inoperative and without benefit of solar or passenger loads. The required capacity shall be available at 480 VAC.

7.3.3 Overhead Heat

Overhead heaters shall be supplied within the evaporator compartment to provide tempering for fresh air and for reheat to maintain humidity control under partial cooling operation of the air-conditioning apparatus. The heater elements shall be located downstream from the cooling coils. The heaters shall be powered from the nominal 480 VAC supply and their power shall be variable to match the thermal and/or reheat loads as required in order to maintain the specified interior temperature and for energy efficiency.

There shall be no exposed, un-insulated, or unprotected high voltage components, wiring, or terminal connections in the heater area, except the heater element coils.

7.3.4 Overhead Heat Safety Devices

The overhead heater circuit(s) shall be protected by dedicated circuit breaker(s). Each stage of overhead heat shall be switched by a solid-state contactor.

Three (3) stages of overhead heater protection shall be provided. They shall include an airflow switch, automatically resettable overheat thermostat, and a manually resettable back-up protection in the form of shunt trip circuit which trips the circuit breaker(s). The details of the overheating protection shall be submitted to SMART for approval **[CDRL 7-02].**

7.3.5 Floor Heaters

Floor heating, if provided, shall use electric strip heaters, powered from the 480 VAC, mounted behind stainless steel heater guards along the side walls at the floor. The heaters shall be uniformly distributed. The floor heaters shall be extended to the cab. As a minimum, the total floor heat capacity shall be divided into stages of approximately 1/3 and 2/3 of total capacity, allowing for HIGH, MEDIUM, and LOW power operation. Proportionally controlled floor heating, using solid-state switching contactors can be provided instead of the 3-staged heating.

The electric floor heater elements shall be of the strip-heater type. The heater elements shall be mounted on approved insulators attached to the carbody. The heater elements shall not be mounted to the heater guard.

Each heater circuit shall have its own circuit breaker and ground fault protection. The ground fault type circuit shall remain latched in the disconnected mode until manually reset by means of a momentary reset button located in the HVAC control box or other approved location. The fault trip must not be affected by control power loss or fluctuation. A tripped ground fault circuit shall be annunciated on the ground fault detection device in the HVAC control box and transmit to the fault monitoring network, if the latter is provided.

Electrical connections to the floor heater elements and the heater guard openings shall be arranged such that electrically live points cannot be reached with a long thin object such as a knife or screwdriver blade inserted through the holes in the heater guard face and section. A probe described in paragraph 7.2 and Figure 7.1 of the UL Standard 1995 shall be used for verification.

All surfaces of the floor heater enclosures accessible to passengers shall be insulated, if required, to limit the surface temperature to the lowest practical value and in no case higher than 125°F (52°C).

The heater guard front panels shall be constructed so that sections may be removed for replacement of heating strips without dismantling seats. The tops of the heater guards shall be sloped to prevent collection of dirt.

7.3.6 Windshield Defroster/Demister

Defrosting or defogging of the Operator's and opposite windshield shall be by means of an electrically heated windshield. The windshield element shall be designed to clear the entire window of frost or fog. The time required to defrost and defog the window shall not exceed 15 minutes at 30ºF (-1°C) ambient and a car interior temperature at layover condition.

7.4 Ventilation

Ventilation of the car shall be accomplished by centrifugal fans supplied as part of each HVAC unit. The evaporator blowers, and the fresh air fans if provided, shall operate to ventilate the car whenever the HVAC system is energized, including conditions when heating and/or air-conditioning functions have failed. The fans shall be powered from the 480 VAC.

The minimum fresh air supply to the car shall not be less than specified in Table 7.1 above.

The system design shall ensure that a minimum interior pressurization of 0.10 inches of water (25 Pa) is maintained in a stationary car with all doors and windows closed and all equipment operating under normal conditions. Positive interior pressure must be maintained at all car speeds regardless of the car's position in a consist or the direction of travel.

The cab door shall be provided with a grille. It shall permit the conditioned air supplied to the cab to return to the passenger compartment.

Fresh air shall be drawn into each air conditioning unit through a screened, weather-protected air intake grill and shall be filtered. The design shall preclude wind-driven rain or snow from accumulating and leaking into the vehicle interior and to ensure no moisture traps or collection points exist.

Fresh and return air shall mix such that the mixed air entering the evaporator coil is at a uniform temperature. Air flow velocity shall be uniform across the entire face of the filters and evaporator coils.

Fresh and return air, or fresh and mixed air, shall be filtered by disposable type, 2 inch thick, pleated media filters of the cardboard frame type in a commercially-available standard size. Filter design shall be in accordance with ASHRAE Standard 52.2 and filters shall have a minimum MERV Rating of 8. Air filters shall meet the requirements of UL Standard 900, Class 2. Air flow face velocity of the filters shall not exceed the manufacturer's maximum velocity at any point of the filter service.

7.5 Cooling Equipment

The air-conditioning system shall be capable of cooling and dehumidifying the car with direct-expansion, electromechanical vapor-cycle equipment using R407C or other SMART approved refrigerant listed in the U.S. EPA SNAP list for Motor Vehicle Air Conditioners for Passenger Train end-use. The refrigerant shall have an ASHRAE Safety Rating of not less than A-1. The Contractor shall provide the acceptable charging procedure for the system charged with the blended refrigerant **[CDRL 7-03].**

The refrigerant system controls shall include an automatic pump-down cycle. Pump-down shall not be initiated if the system shut down is initiated by a protective safety device such as: excessive pressure, temperature, or current protective devices or switched "OFF" via the circuit breaker. In addition, a bump-start should be considered, to provide additional protection against liquid slugging of the compressors on start up such as when following a loss of power.

Proof of airflow shall be required to initiate or maintain compressor operation. A pump down shall be immediately initiated if a loss of airflow is detected while the compressor is operating.

Capacity Control shall be incorporated and should be either infinitely variable, or should have at least three (3) stages.

The design of the evaporator unit shall provide adequate space between the evaporator coil and the heater elements to enable the cleaning of the coil by either back blowing or washing. The coil face area shall be sufficiently large to prevent condensate carryover into the fan plenum or main air duct. In any event, the average coil face velocity shall not exceed 450 ft/min (2.3 m/s) and the maximum coil face velocity shall not exceed 500 ft/min (2.5 m/s) at any point of the coil face.

The refrigerant compressor(s) shall be a hermetic scroll type, suitable for transportation application. The HVAC compressor(s) shall be powered from the 480 VAC supply.

The condenser fan(s) shall be driven directly by 3-phase, 480 VAC motor(s). The motors shall be fully enclosed and rated for wash down applications with permanently lubricated rolling element bearings. A flexible copper strap shall be provided to electrically bond the condenser fan motor frame to the HVAC unit structure. Motor installation, with its shaft vertically up, shall require the application of a slinger on the motor shaft to prevent moisture penetration to the inside of the motor.

The condenser section shall be provided with drains, separate from the condensate drains, discharging water under the car.

All pipe insulation shall meet the flammability and smoke emission requirements of Section 17.

7.6 Controls

7.6.1 Electric Controls

The electrical control compartment shall be provided on each unit. It shall be located within the HVAC unit and accessible through return air opening, or in electrical locker elsewhere on the car. In latter case, two electrical control units may be combined in a single enclosure, but should contain all necessary controls for each unit individually.

A PTE plug shall be located on each HVAC unit, and shall be accessible through the return air opening. If separate control enclosure is provided, PTE connectors shall also be located on the outside of the controls enclosure.

7.6.2 Refrigeration Controls

The refrigeration controls shall be accessible from the return air plenum. As a minimum, the following devices shall be provided:

- Low-Pressure Transducer,
- Back-up Low-Pressure Switch,
- High-Pressure Transducer,
- Back-up High-Pressure Switch,
- Capacity Modulation Transducer(s), as applicable,
- Gage Connection Ports.

7.6.3 Temperature Controls

The control of the HVAC system shall be designed to automatically maintain the car interior temperature, including the cab, at the specified conditions, with or without variable internal heat loads such as passengers, motors, lights, and solar gain. All control components and circuits shall operate from the nominal 120 VAC supply, except for the logic unit which shall operate from the low voltage DC power supply. The sensitivity and accuracy of the controls shall permit the requirements of Section 7.2 to be met.

The final selection of temperature control location and arrangement shall be as approved by SMART **[CDRL 7-04]**.

Local control of the heating and air conditioning shall be fully automatic when the HVAC control system is energized and 480/120 VAC and low voltage DC power is available. An ON/OFF switch shall be provided on the outside of the electrical compartment. With the switch in the "ON" position, the HVAC unit shall operate normally under the control of automatic temperature controller. When turned to the "OFF" position, the switch shall override the commands from the temperature controller and initiate a normal pump-down and shut down cycle.

The HVAC system shall sense air dry bulb temperatures, as required, with thermistor sensors. Thermistors shall be encapsulated in a protective stainless steel tube. Temperature sensors shall be mounted to insure that they are not unduly influenced by local sources of heat, such as motors or resistors, or biased by the adjacent air streams. They shall be easily accessible for maintenance and replacement and protected from damage during routine maintenance and servicing, such as replacing filters. Sensor accuracy shall be as required to comply with the requirements of this Specification.

The static temperature controls shall control the heating, ventilating, and air-conditioning contactors directly through power switching transistors provided as part of the unit without the use of pilot relays.

The static temperature control electronics shall be selected in strict conformance with the specified requirements and shall be packaged in a single, rugged, totally enclosed sheet metal enclosure.

The control systems shall also operate the floor heaters according to the control algorithm necessary to achieve the required interior temperature, including the layover conditions.

Control arrangement, which utilizes the rate of change of the interior temperature as well as the actual value, is encouraged.

7.6.4 Layover Operation

With 480 VAC wayside power and low voltage DC power available, it shall be possible to enable the air conditioning equipment to maintain the interior temperature within the limits specified in this Section. A three-position switch

shall be provided in the cab for layover operation control. The switch shall have "Layover OFF", "Layover Heating" and "Layover Cooling" positions.

Layover heating shall be supplied by the floor heaters and shall maintain an interior temperature of 45ºF +/- 5ºF (7°C +/- 2.5°C). The evaporator blowers shall be disable during layover heating operation.

Layover cooling shall maintain the interior temperature as determined during the vehicle climate room test, specified in Section 18.6.2, item 5.c, such that interior temperature pull-down to 75°F (24°C), without passengers, shall not exceed 10 minutes after the vehicle was exposed to an ambient temperature of 105°F (40.5°C) for 4 hours.

7.7 Air Ducting and Diffusers

Considerations for the air ducting arrangement and construction shall include, but are not limited to, thermal insulation performance as required to prevent condensation on the exterior of the duct under all conditions, acoustic insulation such that the interior noise requirements of Section 2 are met, weight, appearance, and ability to repair. The air velocity within the ductwork is not specifically limited but shall be such that in combination with the acoustic insulation, shape, and diffuser design, the interior noise requirements of Section 2 are met.

On the cab end, the ductwork shall be extended to supply the cab diffusers described below in this Section.

Continuous linear slot diffusers shall be provided throughout entire passenger area of the car. Diffusers shall be as required in Section 3, in a color in accordance with the interior design requirements.

The maximum velocity of discharged air shall not be greater than 150 fpm (0.75 m/s) at 6 inches (150 mm) from the diffusers. Maximum air velocity throughout the car interior shall not exceed 100 fpm (0.5 m/s) at 60 inches (1.5 m) above the floor.

The Operator shall be able to manually control airflow to the cab from full flow to no flow and control the direction of air discharge. Operator's cab diffusers shall not be subject to velocity limitations, however, all interior noise requirements must be met with the cab diffuser set at any flow rate.

The air ducting arrangement and materials shall be submitted to SMART for review and approval **[CDRL 7-05].**

A return air grill or grills shall be provided in approved locations for each HVAC unit. The return air grill shall be of sturdy and rattle-free construction and shall have a surface finish and color in accordance with the interior design requirements. It shall be hinged on one side and provided with approved captive fasteners and two (2) safety catches on the other side. The return air grill shall be designed to pass the required quantity of air with sound levels such that the requirements of Section 2 are met anywhere 1 foot (0.3 m) from the grill. The

grill design shall not allow a direct line of sight from the car interior to the mixed air plenum and shall preclude the introduction of small objects, such as cigarettes, from entering the plenum.

7.8 Fresh Air Intake and Water Eliminators

Fresh air shall be delivered to the HVAC unit as described in Section 7.4. The fresh air intakes shall be separate from the condenser coil(s) air intakes.

The design of the unit shall preclude short circuiting of the condenser coil(s) discharge air into the fresh air intakes.

Water eliminating baffles or louvers shall be provided to prevent water, which enters the fresh air intakes, from being drawn into the unit. Eliminators shall be fabricated from stainless steel. Cleaning and servicing of the water eliminators shall not be required more often than once a year with no significant reduction in the system performance. Fresh air filters shall not be considered part of the water elimination design.

7.9 Smoke Detection

Each car shall have smoke detectors installed in the unoccupied compartment as defined by 49 CFR 238.103, and, if required, in other areas of the car. The detectors shall be powered from the low voltage power system, and shall be rugged, reliable, and vandal proof. The detectors shall not be sensitive enough to detect cigarette smoke, but shall detect smoke in such a concentration, which can be considered a threat to passengers.

When an unsafe condition is detected, the ventilation system on the car shall shut down and activate a trainline audio-visual alarm in each cab. Activation of the alarm shall be recorded in the car level and train level diagnostic systems, if the latter is provided.

Indicators that are activated with the alarm, and are visible on the exterior and in the interior, shall indicate to the crew and rescue personnel the affected car.

The alarm in the cab shall remain on until acknowledged, and the alarm in the affected car shall remain on until reset. 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 and/or accessible to the passengers.

Details of the design, operation, installation and testing of the smoke detection and alarm shall be submitted to SMART for review and approval **[CDRL 7-06].**

7.10 Contract Deliverables

The following submittals are required:

Details of the system capacity and performance calculations, design, arrangement, installation, and operation of the HVAC system

Details of the overheating protection

Acceptable charging procedure for the system charged with the blended refrigerant

Final selection of temperature control location and arrangement

Ducting arrangement and materials

Details of the design, operation, installation and testing of the smoke detection and alarm

The following drawings shall be submitted, as a minimum:

- General views of the HVAC unit and all types of heaters
- Detail drawings of major components
- Installation details and interfaces
- Electrical and piping schematics
- Assembly details
- Controls assembly drawings

8 LIGHTING

8.1 General

The lighting system design and illumination requirements shall meet the Federal Regulations (49 CFR 27, 37, 38, 229, 238, and 239) and APTA Standards and Recommended Practices (APTA SS-E-013-99 and APTA RP-E-012-99) for car lighting. Where a conflict exists, the most restrictive requirement shall apply.

All lighting, except interior passenger lighting, headlights, roof lamps, and cab ceiling lights shall be LED based. All lighting shall be powered from the low voltage dc system

The interior lights shall also comply with 49 CFR 238.115 and APTA SS-E-013-99, “Standard for Emergency Lighting System Design.” Emergency lights may be a subset of the normal interior lights or independent installations. The fluorescent fixture adjacent to each doorway, as well as other specified light fixtures, will be powered directly from the battery to provide emergency lighting during LVPS failure.

The details of the lighting design, arrangement, location, fixture type, reliability and installation shall be submitted to SMART for approval **[CDRL 8 – 1].**

8.2 Lighting Types

8.2.1 Incandescent Lights

Except as required by this Section, the use of incandescent lights for any purpose including indicator lights or general illumination is prohibited,

8.2.2 Fluorescent Lights

All fluorescent lighting shall be powered from the low voltage dc source via rapid-start dc ballasts with a successful service history in rail transit, complying with the requirements of ANSI-C82. The Ballast operating frequency shall be 25 kHz or greater, with a minimum MTBF of 500,000 hours. Easily accessible AMP MATE-N-Lok connectors shall be provided on the ballast for connection of wiring.

It is assumed that fluorescent lighting shall be used as general overhead lighting in the passenger areas; however, alternative lighting arrangements will be considered, such as LED lights.

8.2.3 Light Emitting Diode (LED) Lights

All LED lights shall be powered from the low voltage dc source, providing full illumination within the voltage range specified in Section 9.

With the exception of LEDs used as indicators on circuit boards, the use of single LEDs is prohibited. All LED assemblies shall be designed such that the failure of one LED is visually indicated to maintenance personnel. Individual LEDs and LED assemblies shall have a minimum life expectancy of 100,000 hours.

If dimming is required for any LED, the light output shall be controlled by the use of pulse width modulation; the use of other voltage or current limiting devices is prohibited.

It is assumed the LED lighting shall be used for local, spot, reading, cab overhead, cab indicator lighting and gauge backlighting, however, alternative lighting arrangements will be considered.

8.3 Passenger area light intensity

The illumination shall comply with the performance requirements of APTA RP-E-012-99, latest issue. The illumination shall be directed downward, minimizing glare. It shall be uniform throughout the reading plane in the passenger seating area of the car, providing adequate illumination of surfaces, such as aisles, doors, and advertisements.

8.4 Passenger area light fixture arrangement

The overhead fluorescent or LED lighting fixtures in the main passenger areas shall be ceiling mounted in two parallel rows, recessed and integrated into the interior finish

8.5 Emergency lighting

The emergency lighting system shall comply with the minimum performance requirements of APTA-SS-E-013-99, 49 CFR 238 and 49 CFR 239.

The battery systems shall have sufficient capacity to operate all emergency lights for at least 90 minutes as specified in 49 CFR 238.115.

Emergency lighting shall be evenly distributed throughout the car interior, including the car door areas. Illumination in emergency mode shall meet the requirements of 49 CFR Part 238.115. The emergency lighting arrangement, quantity and location shall be approved by SMART **[CDRL 8 – 2].**

8.5.1 Disaster lights

Self-contained LED disaster light units shall have sufficient capacity to provide a minimum of 90 minutes operation on its own power source. The power source shall be a super capacitor rather than a battery. Light intensity shall comply with the emergency light requirements per APTA SS-E-013-99. The Disaster lighting arrangement, quantity and location shall be approved by SMART **[CDRL 8 – 3].**

8.5.2 Low-Location Exit Path Marking

The vehicle shall be equipped with a low-level exit path marking per APTA SS-PS-004-99, latest Rev., to illuminate the emergency exit path. A passive or active solution may be presented to SMART for approval. The Low-Location Exit path Marking shall be approved by SMART **[CDRL 8 – 4].**

8.6 Power Sources

All lights shall operate from the battery circuit. Lights shall not be wired in series. The system providing power for emergency lights shall be capable of operation in accordance with the requirements of 49 CFR Part 238.115 for a back-up power system.

8.7 Headlights and Auxiliary Lights

The headlights and auxiliary lights shall comply with 49 CFR 229.125, and shall be designed to be aimed and re-lamped by maintenance personnel with minimum effort. The housing shall be of a rugged corrosion resistance construction, approved, and suitable for railroad use. Each light shall be powered by a dedicated power supply from the car battery, incorporating s soft start feature to expand the life of the bulb.

8.7.1 Headlights

A dual headlight shall be installed on the center line at the cab-end of each car, consisting of two white incandescent sealed beam PAR 56 lamps, each one at least 350 watt, 75 V, or approved equal. **[Include in CDRL 8 – 1]**

8.7.2 Auxiliary Lights

Two independent auxiliary lights shall be installed on the cab-end of each car, forming a triangle with the headlight. Each auxiliary light shall consist of one white incandescent sealed beam PAR 56 lamp, at least 350 watt, 75 V, or approved equal. **[Include in CDRL 8 – 1]**

8.8 Marker Lights

Two red marker lights shall be installed on the cab-end of each car, complying with the requirements of 49 CFR 221, and shall be designed to be re-lamped by maintenance personnel with minimal effort.

8.9 Number lights

Two illuminated car number signs shall be provide on the car sidewalls near the cab of each car, powered from the car battery.

8.10 Low Platform Lights

LED platform lights shall be provided at each side of car passenger entrance, illuminating the station platform, and shall comply with the requirements of 49 CFR 38.

8.11 Cab Console and Ceiling Lights

The lights for the cab area shall be designed and arranged to comply with the requirements of 49 CFR 229.127.

A cab console light shall be provided with dimmer control, providing lights for the console without reflecting on the windshield.

8.11.1 Cab Area Gauge Lights

Cab gauges shall be provided with backlights, as appropriate, to assist viewing in low light conditions. All gauge lights shall be provided with dimming capability.

8.12 Exterior Indicator Lights

Each exterior indicator light shall be in a low clearance, corrosion-resistant housing located within the car clearance line and of a design which shall not be damaged by car washing machines.

Each light shall be accessible from the car interior to allow for maintenance and re-lamping.

8.12.1 Door Lights

Each passenger door on the car shall have an amber exterior LED door-open indicating light, the light shall illuminate whenever the passenger door is open. Each door shall have an ADA warning light as specified in section 6.

8.12.2 Brake Lights

Three LED indicator brake lights shall be provided on each side of the vehicle.

- Green indicator light for “Brake Release”
- Yellow indicator light for “Brake Applied”
- Blue indicator light for “Parking Brake Applied”

8.12.3 PTC Lights

One white LED PTC indicator light shall be provided as one of the four indicator lights on the side of each car. The light shall be illuminated when the cab signal system is active on that car.

8.13 Light Control

All lighting shall be protected by circuit breakers. The main passenger area lighting shall be controlled from the MDU. It shall be possible to control the local car's lighting only, the lighting in all cars forward of the local car, or the lighting in all cars rearward of the local car. The platform lights shall be controlled by a switch located in the switch locker. The emergency lights shall be automatically controlled by relays described in Section 17.

The cab lights, auxiliary lights, and headlight shall be controlled by switches on the Operator's switch panel. A cab console light switch with dimmer shall be provided.

The light control arrangement and switch locations shall be subject to approval by SMART **[CDRL 8 – 5].**

8.13.1 Head light controls

The headlight switch shall have 4 positions: OFF, DIM, BRIGHT and FLASHING. In flashing mode the auxiliary lights shall flash as defined in 49 CFR 229.125 (2). Flashing mode shall also be activated automatically for 20 seconds if the horn is blown. It shall be possible to cancel the flashing mode anytime by moving the headlight switch to FLASHING and back to any other position.

8.14 CDRL

8. - 1 Light system design package
8. - 2 Emergency lighting arrangement, quantity and location
8. - 3 Disaster lighting arrangement, quantity and location
8. - 4 Low location exit path marking
8. - 5 Lighting control

9 AUXILIARY ELECTRICAL EQUIPMENT

9.1 Auxiliary Electrical Equipment

All electrical systems shall conform to basic AAR, NEMA, IEEE and NEC standards. Rotating electrical components shall conform to IEC 60349 or IEEE Std 11-2000 for rail and road vehicles. Electrical and electronic control apparatus shall conform to IEC 60571 or IEEE Std 16-2004 for rail vehicles.

Design review packages shall be provided for each major component of the auxiliary power system:

- Auxiliary Power Supply: **[CDRL 09-1]**
- Low Voltage Power Supply: **[CDRL 09-2]**
- Main Battery Charger: **[CDRL 09-3]**
- Main Battery: **[CDRL 09-4]**
- Engine Starter Battery Charger: **[CDRL 09-5]**
- Engine Starter Battery: **[CDRL 09-6]**

The design review packages shall include functional specifications, design descriptions, circuit schematics, parts lists, and mechanical drawings.

9.2 Voltages

The auxiliary train power voltage shall be 480VAC. The power rating shall be sized for the heaviest demand of heating, air conditioning or combination HVAC and all auxiliary loads.

The auxiliary train power voltage shall be used to run the motors of the air-conditioning compressors, condenser and evaporator fans. It shall also furnish energy for floor and overhead heat.

The auxiliary train power voltage shall be reduced, by means of transformers on each car, to 120VAC convenience outlets and other possible single phase AC appliances.

A low voltage system, consisting of a low voltage power supply, battery charger, and 64VDC battery, fed from the 480VAC circuit, shall be provided.

A 24 V battery may be used for engine staring.

9.3 Auxiliary Power Requirements

The auxiliary power system (APS) shall comply with IEC 60287, IEC 60571, and IEEE Std 1476-2000 and provide the following voltages:

- 480V +/- 5%, 60Hz +/- 1%, Three Phase
- 120V +/- 5%, 60Hz +/- 1%, Single Phase
- 74V +25% -30%, Direct Current, for train line interfaces/controls
- 24V engine starter battery, if applicable.

All auxiliary motors shall be of a brushless design.

9.4 Auxiliary Power Supply

The APS system shall be provided on a one-per-car basis or as one centralized system for each married pair. The APS shall normally operate at all times during car service, and shall be designed for minimum power consumption, especially during times of layover.

A rotating field, 480VAC, 3-phase, 60-Hz generator powered by a matching diesel engine may be proposed by the Contractor. This auxiliary power unit shall be operationally independent of all other diesel engines and power generating equipment. It shall be possible to start the diesel generator if starter battery power is available.

A stand-alone diesel generator shall share starting batteries and a fuel tank with the main propulsions diesel engines on the same vehicle. The generator diesel engine shall comply, to the extent practical, with the propulsion engine technical provisions defined in Section 10 and in particular with 40 CFR 89 Tier 4 emissions levels. The fuel supply system and emergency fuel shut-off system shall be consistent with the propulsion engines.

Alternatively, a static inverter complying with IEC 61287-1, powered by the main propulsion engines through the intermediate DC link, may be proposed. The static inverter shall be suitable to provide full output power at a constant 60 Hz over the whole range of the traction power intermediate link voltages. Regenerated brake energy shall be used to operate the auxiliary inverter in dynamic braking.

If the traction diesel(s) are used to provide 480VAC, it shall be possible to use only one engine to provide all auxiliary standby power.

9.5 Low Voltage Power Supply (LVPS)

The 74VDC low-voltage system shall supply: the marker, emergency and vestibule lights, headlights, ATC/PTC, communicating signal, PA, radio and intercom communication, door operators, traction and brake control units etc. The LVPS shall be powered from the 480VAC supply. It shall be possible to start the LVPS upon establishment of the 480VAC in the absence of battery voltage (dead battery start.)

9.6 Main Battery and Battery Charger

9.6.1 Battery

Each car shall have one 50 cell nickel cadmium battery and appurtenances that comply with the applicable requirements of IEEE Std 1536-2002 and APTA RP-E-007-98. The batteries shall use proven non-combustible transparent or translucent cases which comply with NFPA 130 and NFPA 70. The load cycles shall be based on an ambient temperature of 14°F (-10°C). Batteries shall be rated for the indicated operating environment over a normal service life of not less than 10 years.

Nickel cadmium batteries will provide back-up low voltage power in the event of LVPS failure.

A temperature sensor shall be mounted in each battery box to indicate battery temperature to the battery charger.

Thermal switches mounted in the battery box shall be provided to indicate battery over-temperature to the battery disconnect circuit breaker shunt trip circuit.

The battery pack shall have an automated water level topping up system.

The battery compartment shall be sealed towards the vehicle interior and be adequately ventilated towards the exterior.

9.6.2 Battery Charger

The battery charge may be a separate device powered from the 480VAC circuit or it may be a function that is provided by the LVPS. The battery charger shall provide power switching to connect the battery to the vehicle low voltage bus if the battery charger is not functioning and shall provide current limited temperature compensated battery charging current to the batteries when the battery charger is functioning. The charging voltage, current and temperature compensation shall be as recommended by the battery supplier as approved by SMART [Include in **CDRL 09 – 03 and 09 – 05**].

9.6.3 Battery Disconnect Circuit Breaker

A two-pole battery disconnect circuit breaker, breaking both the battery positive and negative, shall be provided for each battery. The circuit breaker shall be explosion proof if mounted in the battery box. When opened the circuit breaker shall completely isolate the battery from all car circuitry. The circuit breaker shall incorporate a shunt trip for the battery over-temperature functions and a series trip for overcurrent. A thermal switch, as indicated above, shall be connected to trip the circuit breaker using the shunt trip function when an over-temperature condition is sensed. A circuit breaker auxiliary contact shall be connected to the MDS system to indicate breaker status.

9.6.4 Emergency Power

Emergency low voltage power shall be provided by the batteries. The batteries shall have the capacity to supply all emergency loads for 90 minutes, complying with 49 CFR 238.115.

9.7 Low Voltage Trainline

A low voltage trainline shall be provided to transmit emergency control power through the train using contacts in the automatic coupler electric portion. The purpose is to permit a car with a functioning low voltage system to power critical control loads on a car with a non-functioning low voltage system. This is so that critical train control and communications circuits can function, allowing the train to be driven from the cab in either car. Logic and power switching shall be provided to shed non-essential loads. This trainline shall not be used to charge batteries.

9.8 Engine Starter Battery and Charger

If a separate engine starter battery and charger is provided they shall comply with the requirements stated above for the main battery and charger except that no low voltage trainline circuit is to be provided.

9.9 Circuit Protection

Circuits and apparatus shall be protected against damage by overcurrent, overvoltage, overheating, voltage transients, and electromagnetic interference.

9.9.1 Source Overvoltage and Overcurrent Protection

The auxiliary power supplies, low voltage dc supplies and battery chargers shall provide automatic overvoltage and current limiting for both device and load protection.

9.9.2 Wiring and Load Overcurrent Protection

Each circuit shall be protected by circuit breakers to protect the wiring and load devices. Circuit breaker status shall be transmitted to the MDS system described in Section 11. Refer to Section 17 for circuit breaker requirements.

9.9.3 Ground Fault Protection

Circuits shall be provided with ground fault detection circuits. Detection of an excessive level of current to ground shall cause the appropriate circuit breaker to be tripped open and shall also be indicated to the MDS system described in Section 11.

9.9.4 Transient Protection

All equipment shall be protected against damage and malfunction by transient voltages. Equipment that is capable of generating electrical transients shall include suppression devices to reduce transient voltages to an acceptable level.

9.9.5 EMI Protection

Shielding and filtering shall be provided to both protect the equipment from damage by externally generated EMI and to prevent it from transmitting EMI. Refer to Section 2.

9.9.6 Low Voltage DC Circuit Isolation

The low voltage system shall not be grounded.

9.10 Shop Power / Layover Power

A weatherproof external auxiliary supply receptacle shall be provided on each side of the vehicle at a convenient location to permit an external 480VAC, 60 Hz, 3-phase supply to be connected to the auxiliary system. The receptacle shall include interlock contacts to control switchgear on the vehicle and in the external power supply, and shall be accessible from the side of the vehicle from TOR level and from high platform level.

The 480VAC shop power / layover power supply shall provide power to the 74V low voltage system and vehicle / starter battery chargers.

9.11 Emergency 480 VAC Trainline Power

A circuit that uses emergency trainline power cables to connect vehicles shall be provided to permit power to be transferred from a vehicle with a functioning 480VAC supply to a vehicle with a defective 480VAC power supply to permit both cars to be operated on the system. Connection of the jumpers shall cause automatic load shedding of non-essential loads. The contractor shall propose a load shedding scheme for approval by SMART **[CDRL 09-07]**

9.11.1 Emergency Trainline Power Receptacles

Waterproof trainline power receptacles shall be provided adjacent to each coupler for emergency trainline power connections. Refer to Section 4 for detailed requirements.

9.12 Electrical Design Requirements

The auxiliary power supply, low voltage power supply and battery charger shall each comply with the electronic control requirements of Section 11.

9.13 Diagnostic Requirements

The auxiliary power supply, low voltage power supply and battery charger shall each incorporate a local diagnostic and test system that complies with the requirements of Section 11.

9.14 120VAC Convenience Outlets

120 VAC convenience outlets shall be provided for use by railroad personnel and passengers. One circuit shall feed duplex outlets on each side of the cab and in each electric locker. A second circuit shall feed duplex outlets on the sidewall adjacent to each passenger seat to power laptop computers. Outlets for passenger use shall be limited to a maximum output power of 150W by means of automatic resettable fuses or other current limiting devices.

Each circuit shall be fed by a ground fault sensing 20A circuit breaker. 120 VAC convenience outlet locations shall be submitted to SMART for review and approval.

9.15 CDRL

The following design submittals are required:

9-01 Auxiliary Power Supply
9-02 Low Voltage Power Supply
9-03 Main Battery Charger
9-04 Main Battery
9-05 Engine Starter Battery Charger
9-06 Engine Starter Battery
9-07 Load Shedding Scheme

10 PROPULSION AND DYNAMIC BRAKES

10.1 General

The DMU traction system shall be diesel engine powered and use either an electric or hydraulic drive system. SMART has no preference as to the propulsion system configuration as long as the design meets the minimum performance requirements of these design criteria.

This Section describes the diesel engines, generators, inverters, transmission units, final drive gear units, control logic, friction brake interface, all accessories necessary to meet the specified propulsion and dynamic braking requirements.

The diesel drive train shall be redundant so that the vehicle can still be operated, presumably at reduced power, if one drive train is not fully functional. The smallest revenue service consist shall be two cars, one married pair or an articulated vehicle. Between those two cars, there shall have a minimum of two independent propulsion and dynamic brake systems.

The propulsion system shall interface with several vital car systems. Traction shall be inhibited unless all doors in the train consist are safely closed and the friction brake system is sufficiently charged and operational. Each propulsion engine shall have an automatic fire detection and suppression system that interfaces with the operator cab, the propulsion control system, and the friction brake system.

10.2 Diesel Engine for Traction Power

All traction power diesel engines shall be of a service-proven design. They shall be identical and fully interchangeable with one another. The diesel engine shall deliver sufficient power to meet the performance requirements of these design criteria.

The diesel engines shall have the following basic design features:

- Water cooled
- Turbo-charged
- Electronic fuel injection
- Self protection
- Low temperature starting capability
- EPA Tier 4 certified

Each diesel engine and associated close-coupled traction power equipment shall be mounted on a unique structural sub frame for modular removal from the car. The engine shall be resiliently mounted to the sub frame and the sub frame resiliently mounted to the car. The mounting system shall meet the shock and vibration criteria stated in Section 2 while minimizing noise and vibration transmitted into the passenger areas.

The diesel engines shall not require a major overhaul (engine disassembly) within fewer than 12,000 service hours when operating the car according to the planned duty cycle. Oil change shall not be necessary more often than every 500 service hours or 45 days.

The engine shall be packaged to allow easy access to all elements scheduled for service less than or equal to every 180 days. Here, easy access shall be defined as not requiring the removal of any belts, fluid-containing elements, or exhaust system components not directly related to the scheduled maintenance task. Engine compartment access shall be provided through removable access panels on either side of the car and from below. Test ports shall allow service personnel to collect samples of engine oil and coolant while kneeling beside the car. Filling, draining, and checking all polluting components such as oil, grease, and coolant shall be done from the outside of the car passenger area. At a minimum, the following items shall be easily serviced through side access doors:

- All fuel, engine oil, and associated filter elements;
- Engine oil level dip stick or sight glasses, oil fill port, and drain ports;
- Engine start panel;
- Water and lubricating oil pumps;
- All visual indicators, gauges, protective devices and test connection points for engine coolant, lubricating oil, fuel oil, and combustion air.

The Contractor shall submit a maintainability study to the Engineer to show that access is ergonomically appropriate to frequent service points on the engine cradle. **[CDRL 10-001]** It shall show the path through which parts will be visually inspected or removed and replaced during scheduled maintenance activities. It shall also list the frequency of required access or removal.

10.3 Engine Starting System

All on-car diesel engines shall be equipped with electric starter motors, preferably operating at nominally 24VDC. Pneumatic starters are not acceptable.

An independent battery system shall be provided for diesel engine starting. Batteries may be nickel cadmium or lead acid. Starting the engines shall not impact the vehicle low voltage control power supply.

The starter batteries shall have the capacity to start the propulsion engine(s) and auxiliary power generator (if applicable) sequentially. If the car is equipped with multiple engines, each engine shall have some means, preferably an alternator, to charge the engine starter batteries such that any one engine can replenish the starter battery system. Starter battery capacity shall not be dependent on engine start order, specifically starting an auxiliary power generator before starting the propulsion engine(s).

Engine start batteries shall be capable of supplying engine starting current, as defined by the engine supplier, over the full range of environmental conditions defined in Section 1 of these design criteria. Batteries shall be sized to allow one diesel propulsion engine to be cranked for 10 seconds, rested for 20 seconds,

cranked for 10 seconds, rested for 20 seconds, and cranked for 10 seconds without being recharged during this time.

Refer to Section 9 for other battery requirements.

10.4 Engine Cooling System

Each engine shall have its own cooling system. If diesel hydraulic propulsion is proposed, the system shall cool both the engine and transmission/retarder.

The cooling system shall consist of the radiators, expansion tank, temperature sensors, controllable valves, and fans to regulate the cooling air volume. The cooling controls shall keep the engine temperature in the specified optimum operating range under all operating conditions. The radiators shall be mounted on the roof for maximum access to clean, ambient air.

The cooling media shall consist of a mixture of water and corrosion inhibitor/antifreeze. The media shall be captive, with no automatic drain valves as might be found in locomotives. The coolant shall provide freeze protection over the range of environmental conditions described in Section 1 with at least a 10-degree margin of safety. The coolant shall provide boiling protection over the anticipated range of operating temperatures.

Coolant shall flow in stainless steel, copper, or brass piping. No flexible hoses shall be used except for direct connection to the engine and radiator to provide dielectric isolation and allow limited relative component movement. Swivel-threaded, hydraulic-type hose assemblies shall be used for such applications. System filling and draining valves shall be easily accessible.

The radiators shall be of service proven design, made of either copper or aluminum. Connections shall be provided with couplings to facilitate removal and replacement.

The cooling system shall be designed to work over the SMART duty cycle, in the range of environmental conditions described in Section 1 and allow for a minimum of 25% contamination of the cooling surface. The contractor shall submit cooling system thermal capacity design calculations for approval **[CDRL 10-002]**. Calculations shall include propulsion loads, dynamic braking loads, and engine intake manifold air temperatures (see Section 10.2.4).

Sufficient airflow over the engine block shall be provided to comply with the engine manufacturer's recommendation for convective cooling, accounting additional heat from proximate equipment that may include the exhaust system and charge air cooler. Ambient temperature near the engine shall be monitored and the operator warned if allowed to exceed the lesser of the engine supplier's recommendation or 200°F (93°C).

10.5 Preheating

A preheat unit shall heat the cooling media to the temperature needed to start the engine safely, as specified by the engine supplier. The preheat unit can be

powered either electrically by the shop power or by diesel fuel from the onboard tank. If a diesel burner is used, the unit shall be fully functional with the available onboard power.

The Contractor shall determine if the charge air needs to be pre-heated to avoid excessive exhaust emissions during the engine start at the lowest temperature specified in Section 1. The engine supplier shall state the lowest temperature at which it is possible to start the engine without preheating in case of an emergency.

10.6 Charge Air Cooling

An air-to-air charge air cooler shall be used, designed to meet the engine cooling requirements and the environment conditions as described in Section 1. The cooling surface shall be sized for at least 25% contamination.

The cooler and the turbo charger connections shall be equipped with service proven flexible connections which shall provide vibration isolation through the range of the charge air pressure.

10.7 Engine Exhaust System

Each engine shall be equipped with a silencer to reduce engine noise to be in compliance with 40 CFR 201 and 40 CFR 210. Engine operation with the silencer shall comply with noise levels defined in Section 2.

The exhaust pipes and silencer(s) shall be constructed of stainless steel. The exhaust piping system shall allow for heat expansion. All connections shall allow an easy exchange of the exhaust system parts.

Approved non-asbestos high-temperature insulation shall be applied, where required, to minimize thermal radiation to heat-sensitive equipment or where the exhaust tubes may present a safety hazard to passengers, service personnel, or equipment.

The exhaust gases shall be released to the environment in a suitable location on the roof. Exhaust gases shall not interfere with any fresh air intake under all car-operating conditions.

One or more exhaust after treatment device(s) are expected to be installed as part of the diesel engine emissions compliance. The Contractor is encouraged to combine devices, such as the silencer with the diesel particulate filter, as current product technology allows.

10.8 Fuel System

The fuel system shall comply with 49 CFR 238.223 and 49 CFR 229.93/95. Fuel tank venting shall be in accordance with 49 CFR 229.95.

The fuel system shall consist of a fuel tank, common to all engines on one car, two fuel filler pipes (one on each side of the car), equipped with SMART-

approved fuel level switches for the automatic fuel pump shut-off valve, two analogue fuel level gauges (one per side) adjacent to the filler pipe, fuel filters, and interconnecting pipes or hoses. The fuel system shall be primarily separated from the engine cradle(s).

Fuel lines shall comply with APTA SS-C&S-007 Section 5. They shall be fabricated from stainless steel tubing with minimal use of reinforced, fuel-rated flexible hose, limited to transitions between tubing, filters, the engine, the fuel tank. The Contractor shall only use swivel-threaded hose assemblies for such applications.

The diesel systems shall use fuel meeting or exceeding American Society for Testing and Materials (ASTM) standard D 975 as applicable at the time of car acceptance. Fuel shall meet, at minimum, ASTM D 975 No.2-D S15, known as Ultra Low Sulfur Diesel (ULSD), containing a regulated maximum sulfur content of 15 parts-per-million (ppm).

The fuel tank capacity shall be sufficient to ensure continuous operation in SMART service, as defined in these design criteria, for at least one full day before refueling. The Contractor shall submit calculations supporting the fuel tank sizing. **[CDRL 10-003]**

10.9 Emergency Fuel Shut-Off System

An emergency fuel shut-off system, compliant with 49 CFR 229.93 shall be provided.

10.10 Engine Control System

Engine operation shall be controlled by an electronic control unit (ECU). The control unit shall have a connector for a portable test unit (PTU) to permit static testing, access to diagnostics, and monitoring of the traction system during car operations. All major operating parameters, such as engine temperature, speed, and fault conditions, shall be reported to the car monitoring and diagnostic system.

10.11 Fire Protection System

Temperature sensors near each engine shall detect excessive heat levels. If the trip level is reached, an automatic fire suppression system shall be discharged. Upon fire detection, all engines on the affected car shall be immediately shut down and the fuel supply stopped at the fuel tank. A trainlined fire alarm shall be displayed in the active cab.

10.12 Emission Control

Exhaust gas emissions from the diesel engines shall comply with 40 CFR 89 for the Contractor-selected engine power rating and the anticipated date of first car delivery. Engines are expected to comply with Tier 4 levels. The Contractor shall submit a letter documenting the emissions compliance of the proposed engine. **[CDRL 10-004]**

10.13 Diesel Electric Drive

If a diesel electric drive is proposed, the traction power diesel engine shall be coupled to a matching alternator. The alternator shall provide electric power to traction inverters and potentially an auxiliary inverter. The traction inverters shall provide a variable-voltage, variable-frequency (VVVF) output to drive the traction motors. Each VVVF shall drive one or more traction motors in one truck.

10.14 Alternator

The alternator unit shall consist of the excitation circuit, output rectifier, protection circuits, and the corresponding controls. The excitation shall be provided by a car battery, at 72VDC or 24VDC nominal, and shall be functional over the full battery voltage range but not less than +25% -30%.

The alternator controls shall be part of the car controls to allow an optimum control of the power generation, as needed by the traction and auxiliary inverters. Any fault conditions or irregularities shall be reported to the car controls and diagnostic system.

Asynchronous generator may be proposed.

If the alternator is not close-coupled to the traction engine, then it shall be resiliently mounted to a sub frame and the sub frame resiliently mounted to the car in a similar manner as the engine. The mounting system shall meet the shock and vibration criteria stated in Section 2 while minimizing noise and vibration transmitted into the passenger areas.

10.15 Inverter

Power modulation in both propulsion and dynamic braking shall be accomplished by microprocessor-controlled, insulated-gate, bipolar-transistor (IGBT) VVVF inverters. The inverter shall power up to two self-ventilated traction motors in parallel in each power truck. Each inverter shall be completely independent and shall allow continuous operation of one power truck if one inverter is cutout.

The Contractor shall have responsibility for the complete sizing, coordination and integration of the inverter system with the diesel generator, controls, input filtering, loads, load management, fault condition control and annunciation and fault protection.

Inverter unit cooling shall be accomplished by passive means or forced air-cooling. No external air shall pass over energized surfaces.

Each inverter shall protect itself from over temperature by performance reduction such as cutting out dynamic brakes. If the overheat conditions persist, the inverter may shut itself down completely and signal “Inverter/dynamic” brake failure to the monitoring and diagnostics system.

The inverter drive control system shall be a modern vector control system, with sufficient accuracy to provide stable operation at any speed, including standstill.

Inverters shall comply with IEC 61287-1 and operate over the full range of the intermediate DC link voltage.

Power semi-conductor devices, their drivers and associated assemblies shall be grouped in readily removable phase modules that are designated as line replaceable units (LRU). The IGBT module shall be the LRU.

The inverter controls shall be fully integrated into the vehicle control system as defined in Section X of these design criteria.

10.16 Traction Motors

All traction motors shall be identical and applied one per powered axle as necessary to achieve the vehicle performance requirements of this specification. The traction motors shall be three phase, squirrel cage induction motors, with welded copper cage, and form-wounded stator coils. Motors shall be self-ventilated, insulted with IEC Standard 85, Class C, but dimensioned for one class less based on the duty cycle specified in Section 2. The motor enclosure and ventilation system shall be designed for potential undercar environmental conditions and water spray. Traction motors shall be of a service-proven design with a strong history of commuter rail service.

Applicable Motor Standards are IEC 60349 or IEEE Standard 11.

10.17 Gear Drive

Gear units shall be nose-suspended or fully-suspended parallel drives with helical gears designed to comply with requirements of this specification. Support and torque reactions of the gear unit and traction motor shall be transmitted to the truck frame through resilient mounts which shall not restrict the movements allowed by truck frame.

Bearings shall have an ANSI/AFBMA L10 rating life equivalent to 1,000,000 miles (160,000,000 km) or more of service.

Gears shall be designed and applied to require inspection and adjustment no more frequently than once in every 500,000 miles (805,000 km) and have a life of at least 1,000,000 miles (1,600,000 km).

Gear units shall be oil lubricated and provided with sufficient baffles, dams, and passages to ensure an adequate flow of lubricant to bearings and gears under all conditions of speed, load, temperature, and weather, including continuous operation in either direction at maximum speed. Gear units shall be designed to prevent infiltration of moisture into the lubricant from any and all sources. The gear units shall have a minimum oil level check interval of 30,000 miles and a minimum oil addition interval of 60,000 miles. They shall not require replenishment of oil at a rate in excess of one liter for every 100,000 miles (160,000 km).

10.18 Dynamic Brake System

The car shall have a dynamic brake system. Dynamic brakes shall be automatically blended with the friction brakes to minimize use of friction brakes while producing the required service braking rates as specified in Section 2. The dynamic brakes shall not be applied through independent operator command.

The dynamic brake resistors shall have sufficient capacity to provide full power dissipation during operation at full service braking over the specified profile and at maximum passenger loadings.

Resistor grids shall be electrically isolated from their frames, and the frames electrically isolated from the car body. Provision shall be made for grid expansion to prevent warping. The resistor grids shall be convection ventilated and roof mounted. Screens shall protect resistors from damage.

The brake resistors and the wire routing to the resistors shall not cause electromagnetic or acoustic emissions during dynamic braking.

Resistor grid and all metallic frame materials shall be stainless steel.

It shall be possible to cut out the dynamic brakes by means of a sealed switch.

10.19 Diesel Hydraulic Drive

If a diesel hydraulic drive is proposed, the traction power diesel engine shall be coupled to a hydraulic torque converter/transmission, which in turn, is coupled to the drive axle(s) by a cardan shaft and final drive gear unit. Each transmission shall drive one or more axles on one truck.

10.20 Hydraulic Torque Converter/Transmission

The transmission shall have a strong service record in the commuter rail environment, with similar speed and torque loading as projected for SMART service.

The torque converter/transmission assembly shall have openings with removable plugs located with easy access for filling and draining. Plugs shall be suitably located and be of a type that will not be damaged by obstacles on the track, in order to prevent the resultant loss of lubricant. Plugs shall be secured by lock wires, lock tabs or other approved means to prevent loosening in service.

Oil change shall not be required more frequently than every 155,000 miles (250,000 km) or 5,000 operating hours. The filler plug opening shall be arranged to provide an indication of oil level and also to prevent overfilling. Transmission operating fluid shall be available in North America from more than one supplier.

A major overhaul shall take place only after at the minimum of 750,000 miles (1,200,000 km) or 18,000 operating hours.

All logic units controlling traction and/or braking functions shall be based on service-proven microprocessors and associated peripherals and I/O, as required to meet all of the specified functions and performance criteria. See Section 11 for control requirements.

At a minimum, the following items shall be easily serviced through side access doors or a service pit below the car:

- All transmission oil filter elements;
- Transmission oil level dip stick or sight glasses, oil fill port, and drain ports;
- All visual indicators, gauges, protective devices and test connection points for the transmission

If the transmission is not close-coupled to the traction engine, then it shall be resiliently mounted to a sub frame and the sub frame resiliently mounted to the car in a similar manner as the engine. The mounting system shall meet the shock and vibration criteria stated in Section 2 while minimizing noise and vibration transmitted into the passenger areas.

10.21 Final Drive Gear Units

Gears shall be designed and applied to require inspection and adjustment no more frequently than once in every 500,000 miles (800,000 km) and have a life of at least 1,000,000 miles (1,600,000 km).

Gear units shall be oil lubricated and provided with sufficient baffles, dams, and passages to ensure an adequate flow of lubricant to bearings and gears under all conditions of speed, load, temperature, and weather, including continuous operation in either direction at maximum speed. Gear units shall be designed to prevent infiltration of moisture into the lubricant from any and all sources. The gear units shall have a minimum oil level check interval of 30,000 miles and a minimum oil addition interval of 60,000 miles. They shall not require replenishment of oil at a rate in excess of one liter for every 100,000 miles (160,000 km).

10.22 Cardan Shafts

The cardan (drive) shafts shall have a double universal joint, splined arrangement, and shall be torsionally resilient to cushion torsional shocks between the truck and the transmission. The damping characteristics and power rating selected shall meet the transmission manufacturer's recommendations. The cardan shaft shall be designed for the worst-case track curvature and route-specific speed/curvature profile.

Cardan shaft safety hangers shall be provided and shall meet the requirements of 49 CFR 229.99.

10.23 Dynamic Brake System

The car shall have a dynamic brake system. Dynamic brakes shall be automatically blended with the friction brakes to minimize use of friction brakes while producing the required service braking rates. The dynamic braking effort may vary with car speed, but shall provide measurable braking force down to at least 10 mph. Dynamic brakes shall comply with the requirements of Section 2.

The dynamic brakes shall not be applied through independent operator command.

A hydrodynamic retarder integral to the transmission shall be provided. The transmission retarder shall convert car kinetic energy into heat by means of fluid shear within the transmission operating fluid. This heat shall be rejected to the transmission cooling system and ultimately to an air-to-water or air-to-oil heat exchanger. The retarder should be rated for steady state operations of at least 60% of the maximum tractive effort rating of the drive train. The transmission cooling system shall be designed with enough fluid volume to handle single car stopping efforts well in excess of the rated, steady-state retarder output.

The transmission cooling system, if not the same as the engine cooling system, shall follow the same design criteria as stated above.

It shall be possible to cut out the dynamic brakes by means of a sealed switch.

10.24 Environmental Sustainability

SMART is committed to environmental sustainability, whereby rail construction and transit equipment shall comply with all applicable current environmental regulations and work to embrace new regulations, standards, and technologies as they are developed and implemented. The diesel traction power equipment shall comply with regulations in place at the time of first car delivery. System design and packaging shall also look at the next generation of technology and provide enough flexibility and/or packaging volume to allow, to the extent possible, retrofitting as these technologies are brought to market. This shall include, at minimum, progressions in fossil fuels, progressions in renewable bio-fuels, independence from foreign energy sources, reduced tailpipe emissions, exhaust aftertreatments, reduced system noise emissions, alternative engine control schemes, and on-board energy recovery, storage, and reuse. SMART will give strong preference to diesel power generation equipment that addresses progressive technology improvement in a changing environmental policy and energy economy.

The Contractor shall propose an emissions compliance plan **[CDRL 10-005]** for the first 15 years of car operations. This shall include anticipated dates of propulsion engine rebuild or repower. At each major engine maintenance interval, the Contract shall state the expected applicable emissions regulations and any emissions control system modifications required to maintain propulsion engine compliance. Through this plan, the Contractor shall anticipate any significant changes in the propulsion and exhaust system packaging and provide reasonable space allowance for such future modifications.

The Contractor shall propose how the cars can use renewable fuels **[CDRL 10-006]**. At minimum, they shall consider California-produced bio-diesel. The Contractor shall provide a letter from the engine manufacturer(s) stating the maximum blending of bio-diesel with petro-diesel that may be burned in the engines while maintaining warrantee. The Contractor shall further state the maximum bio-diesel blend that may be burned without regard for engine warrantee. These concentrations may need to change seasonally to meet the expected environmental conditions, specifically temperature.

Maintenance procedures shall minimize waste and especially the discharge of hazardous materials. Maintenance procedure considerations shall include sight glasses in favor of dip sticks, drain and sampling ports that provide clear access to containers to minimize spilling and dripping, fill ports that allow quick and clean access from bulk containers, and the maximization of shop power during cleaning, maintenance, and warm-up.

10.25 CDRL

The following submittals are required:

10-1 Maintainability Study

10-2 Cooling System Thermal Capacity Calculations

10-3 Fuel Tanks Sizing Calculations

10-4 Engine Tier 4 Emission Certification Letter

10-5 Emissions Compliance Plan

10-6 Renewable Fuels Compatibility Statement

11 ELECTRONIC CONTROL, SOFTWARE AND MDS SYSTEM

11.1 Electronic Design Standards

All electronic control equipment shall comply with the requirements of IEC 60571, Electronic Equipment Used on Rail Vehicles, Class TX or IEEE Std 16, IEEE Standard for Electrical and Electronic Control Apparatus on Rail Vehicles, latest revision. Refer to Section 17 for material and workmanship standards.

11.2 Vehicle Control Logic

The control logic units shall be microprocessor-based with associated peripherals and I/O, as required, to meet all of the specified functions and performance criteria. All I/O signals shall have galvanic isolation. The control units shall provide self-diagnostic routines, fault monitoring of internal and external devices, and user programmable operating characteristics. Control programs shall be stored in field-programmable, non-volatile memory.

Independent control logic units and logic power supplies shall be provided for each inverter/drive, such that one inverter/drive can function if one has failed.

Electronic control equipment shall be both physically and electrically segregated from power equipment. Control circuitry and control voltage sources shall be isolated from power circuitry and high voltage sources by using opto-couplers or transformers.

The control system shall be powered by dedicated, transformer isolated, power supplies powered from the vehicle battery circuit.

The control unit shall provide continuous monitoring of critical parameters, such as engine operating conditions, motor currents, switching device currents, transmission conditions, cooling air flow and component temperatures. The control unit and all related software and devices shall be sufficiently responsive to detect and remedy all erroneous or potentially damaging conditions such that equipment damage is prevented or minimized.

11.3 Vehicle Data Network

All vehicle control units and diagnostic displays shall communicate with each other by means of a vehicle bus, compliant with existing proven vehicle standards, such as MVB, CAN, or Ethernet as defined in IEEE 1473, latest revision. The bus shall be redundant, fast and reliable.

Safety relevant bus members, such as door controls and friction brake controls, shall continue to operate safely even if the network has failed. Adequate comfort restrictions are acceptable in such a case.

This network shall also be used to synchronize all sub-system clocks within the vehicle with the official time signal, as received by the GPS system.

The contractor shall provide a description of the vehicle data network for SMART review and approval **[CDRL 11-1]**

11.4 Train Data Network

The carbuilder may provide a Train Data Network (wired train bus WTB) to communicate between vehicles. Such a WTB shall comply with IEEE 1473 type T.

The contractor shall provide a description of the train data network for SMART review and approval. **[Include in CDRL 11-1]**

11.5 Monitoring and Diagnostic System (MDS)

11.5.1 General

The Monitoring and Diagnostic System shall be a physically-distributed, functionally-integrated system which monitors signals and events within the car and within selected subsystems on the car and stores the collected subsystem, car, and train data in non-volatile memory, located within the selected subsystems and at a central data storage point on the car. It shall be capable of remote viewing/operation via secure wireless link.

Each car shall be provided with a Local Diagnostic and Test System (LDTS) for each individual subsystem as required herein and with a Central Diagnostic System (CDS), which shall integrate the individual LDTS of the various subsystems and sensors on the car.

The Contractor shall prepare a design report on the MDS system for SMART review and approval, **[CDRL 11-2]**, the report shall include:

- Functional specification of the system;
- Mechanical specifications of the system;
- Software design description;
- Mechanical assembly drawings with weights, dimensions, and parts lists;
- Electrical schematic drawings for system interconnections;
- Electrical schematic drawings for each device and assembly; and Installation drawings.

11.5.2 Fault Management

Diagnostic and failure reporting shall be provided at levels of detail appropriate for the operating or maintenance function being supported. Data points shall be associated with fault attributes which can be changed by SMART personnel.

Operating and maintenance functions that shall be considered include the following:

- Operating Failure Identification and Correction

  The Diagnostic System shall provide the Operator and other train crew members, where appropriate, information concerning failures affecting train operation that they should be aware of, either because the failure is safety-related, the failure affects crew operating procedures, or the failure is correctable by the Operator or a train crew member.

- Status Assessment

  The Diagnostic System shall provide sufficient information to enable maintenance personnel to assess, prior to entry into service, the operational readiness and suitability for service of each car.

- Troubleshooting

  The Diagnostic System shall provide detailed data sufficient to guide maintenance personnel using troubleshooting procedures to isolate and diagnose faults down to the lowest level possible. This capability shall be built into the car borne Diagnostic System hardware and embedded software to the greatest extent practical; however, use of Portable Test Unit (PTU) will be permitted, subject to the approval of SMART **[Include in CDRL 11-2].**

- Intelligent Failure Screening

  Each subsystem shall have sufficient diagnostic intelligence to enable it to distinguish between actual subsystem failures and apparent failures caused by failure of another subsystem. For example, inverter failures causing loss of three-phase power to an HVAC system shall not be reported as an HVAC system failure. Power-up and shut-down sequencing among subsystems shall not generate failure messages. In addition, repeated instances of the same failure shall be handled such that LDTS memory is not filled with multiple occurrences of the same failure.

11.5.3 Local Diagnostic and Test System

At a minimum, but not limited to, the following subsystems shall have a LDTS:

- Low Voltage System (LVS)
- Door and Door Control System
- HVAC System
- ATC/CSS/PTC System
- Friction Brake System
- Compressed Air System (may be combined with the brake system LDTS)
- Communications System
- Propulsion System, including diesel engines and associated auxiliaries
- Auxiliary Power System
- Diagnostic System
- Event Recorder System
- Network System

11.5.4 Cab Display

A display, as part of the network described above, shall be provided in each cab. It shall be automatically activated in the activated cab. In the non-activated cab, it shall be possible to activate the display manually. The display shall provide automatic brightness adjustment and shall be easily readable under all adverse lighting conditions including bright sunlight.

The display shall default to the operating status screen upon power up and while the vehicle is in motion, showing important information such as system status and conditions of all subsystems monitored to the driver. Failures shall be annunciated by highlighting the subsystem shown on the display in which a fault occurred.

This status screen shall also indicate which doors are closed, released or open.

If the vehicle is at standstill, additional screens may be activated by the driver to display more information. assisting the driver in failure reset or isolation.

Maintenance mode shall be password protected and allow displaying more detailed information than in the operating mode.

If the display is in “maintenance mode” no viewing restrictions shall apply.

11.5.5 Portable Test Units (PTU)

A centralized diagnostic port shall be provided to connect a PTU to monitor vehicle bus traffic and to download fault logs from all interconnected control units.

Independent PTU connection points at major control units, such as diesel engine controls for example, are acceptable. For such equipment it is expected that at least top level fault information is still made available on the vehicle bus. Detailed fault information will then be accessible by the PTU on the local connection.

Portable test units shall be Windows based laptop computers. They shall have the necessary interface adapters and be configured with all necessary software to connect to the vehicle bus or to specific electronic control units to display in real time all actual vehicle and subsystem operating conditions. The Contractor shall provide back-up copies of all PTU software to SMART **[CDRL 11-3]**.

11.6 Vehicle Software and Systems

Software may be written in a high or low level language. The language, and its implementation for the selected microprocessor system, shall be commercially available in English.

All software, whether interrupt based or polled, shall always assign the highest priority to safety related tasks.

Software shall perform the following basic functions:

- Implement the desired control scheme such that the specified performance is achieved
- Monitor all inputs for unsafe, erroneous, or unknown conditions or combinations of conditions
- 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.
- Limit all output commands to safe levels regardless of any combination of input conditions
- Perform self diagnostic routines and responds promptly, safely, and predictably to detected faults

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

- Permit thorough interrogation of all input, output, and internal conditions by external diagnostic equipment

11.6.1 Software Quality Assurance and Documentation

The Contractor shall submit, for approval, a Software Quality Assurance Plan in accordance with ANSI/IEEE Standard 730, latest revision **[CDRL 11 – 4] and 49 CFR 238.105.** For reference, the Standard has the following minimum software documentation requirements:

- Software Requirements Specification **[CDRL 11-5]**

- Software Design Description **[CDRL 11-6]**

- Software Verification and Validation Plan **[CDRL 11-7]**

- Software Verification and Validation Report **[CDRL 11-8]**

- User Documentation **[CDRL 11-9]**

The Software Design Description (SDD) shall be in accordance with ANSI/IEEE Standard 1016, latest revision. The final Software Design Description shall include detailed graphic program flow information and an input/output port map **[CDRL 11-10]**.

11.7 CDRL

The following submittals are required:

11-1 Vehicle Data Network
11-2 Monitoring and Diagnostic System
11-3 Portable Test Unit Software
11-4 Software Quality Assurance Plan
11-5 Software Requirements Specification
11-6 Software Design Description
11-7 Software Verification and Validation Plan
11-8 Software Verification and Validation Report
11-9 User Documentation
11-10 Final Software Design Description

12 TRUCKS AND WHEELS

12.1 Trucks

12.1.1 General

Each car shall be equipped with two, two-axle trucks. The trucks shall be built as four-wheel, bolster supported, roller journal bearing trucks. Truck weight shall be kept to a minimum consistent with the strength, performance, and maintenance accessibility requirements of these Design Criteria. The suspension shall be designed to support safe, comfortable and stable riding at all speeds as described in the performance section above.

Primary and secondary suspensions shall be designed to be compatible with vehicle weight, track characteristics, ride quality requirements, and level boarding requirements.

Power car trucks shall be specifically designed to accommodate the specified propulsion equipment, with a strong history of commuter rail service.

Trucks shall be suitable for operation at speeds up to 79 mph over the entire range of wheel wear, with qualification at 90 mph. They shall provide a comfortable ride at all speeds to meet the ride quality requirements. Truck design shall prevent “hunting” of the truck at all speeds, while at the same time allowing the cars to negotiate the curves specified in Section 2 without causing excessive flange or rail wear.

Trucks shall conform to all applicable AAR, APTA and FRA requirements, specifications, standards and recommended practices.

The trucks shall be designed to accommodate the friction brake equipment described in Section 13.

12.1.2 Design, Analysis and Testing

The contractor shall follow all of the guidelines provided in the latest revision of APTA RP-M-009-98 to demonstrate through design, analysis, and testing that the truck conforms to the requirements of these Design Criteria.

The contractor shall submit, prior to truck and bolster manufacturing and testing, a stress analysis of the truck frame and bolster parts **[CDRL 12-1]**. The stress analysis shall consist, at a minimum, of a finite element analysis (FEA), supplemented as necessary by manual or computerized calculations.

Test results shall be submitted per Section 18 of this document.

12.1.3 Truck-to-Carbody Connection

Mechanical safety connections shall be provided between the carbody and truck to meet design load transfer requirements and to meet 49 CFR Part 238.219. A positive means shall be provided such that the truck can be raised with the carbody when the car is lifted.

12.1.4 Equalization and Dynamic Performance

The vehicle shall safely negotiate FRA track Classes 1 through 4 as defined within 49 CFR Part 213, at speeds up to the Class-specific maximum allowable operating speed for passenger equipment, as defined in 49 CFR 213.9.

12.1.5 Height Control Valves (If Applicable)

A service proven arrangement of leveling valves shall be provided to control air spring height through the flow of air to and from air springs. The location and number of height control valves shall be a service-proven arrangement.

Air spring height shall be controlled by valves on each truck to compensate for changes in passenger load and distribution. The height control valves shall be oil-filled, with a mechanical valve actuating arm. The valves shall have a response dead band of 1/8 inch maximum when measured perpendicular to the free end of the valve actuating arm, and a mechanical response delay of 2 seconds.

All height control valves shall be readily accessible for maintenance. If it is possible for the leveling valve to freeze in cold ambient conditions, a protective heater or other approved protective device shall be provided.

The air springs on each truck assembly shall be cross-connected through a compensating valve, so that a deflation of one air spring will deflate the other. The compensating valve activation shall be based on a selected pressure differential between the two air bags in a truck.

12.2 Wheels, Axles, Bearings

Wheels shall be wrought steel, E-40 design, Class B, 1:40 tread taper, with a narrow flange. The carbuilder shall develop a wheel profile that supports the vehicles operating characteristics to optimize the dynamic stability and the ride quality. The recommended profile must meet the track geometry as well as track maintenance criteria of the UPRR and the BNSF and must be approved by SMART **[CDRL 12-2].**

Axles shall comply with AAR Specification M-101 grade “F”.

Journal bearings shall be greased, lubricated roller bearings or equivalent with plug access hole to facilitate wheel truing. Bearing shall meet L10 life of not less than 3 million miles at an AW2 car weight.

Wheel and axle assembly including wheels, axle, brake disc hubs, journal bearings, gear box, speed sensor gear ring and ground brush ring shall be assembled in accordance with the latest standard AAR practice. Wheel, bearing seat, and brake disc hub pressing chart shall meet the latest AAR Manual of Standards and Recommended Practices, Section G-II, Wheel and Axle Manual.

12.3 CDRL

The following submittals are required:

12-1 Stress analysis

12-2 Recommended wheel profile

13 FRICTION BRAKES

13.1 General

The friction brake system shall function in coordination with the propulsion system. The system shall provide independent brake pressure control for each truck. The brake system shall comply with 49 CFR 238.231. In this section, dynamic brake shall mean a wear-free electric or hydrodynamic brake.

The brake performance shall be in accordance with the requirements specified in Sections 2.

Each axle shall have a disk brake system. Brake pads shall be replaceable without disassembly of the brake caliper or other vehicle components. Additionally, the carbuilder may propose a thread brake on some of the axles in addition to the cleaning pads specified in section 13.7.

The friction brake system shall perform the following basic functions:

- Capable of stopping an AW3 loaded train as specified in section 2
- Supplement dynamic braking and provide service braking under all vehicle loadings, when the dynamic brake is not available.
- Provide emergency braking.
- Incorporate a parking brake system.

The friction brake system shall have the following configuration:

- Each axle shall have a load-weight-compensated friction brake to provide the braking effort needed to have an evenly distributed adhesion coefficient for all trucks in a train.
- Each truck shall be controlled independently by its own brake control unit.
- Allow a Class I brake test to be conducted without requiring a pit or an inspector breaking the plane of equipment.

The friction brake system is assumed to be pneumatically actuated. Brake pipes shall allow air connections through the automatic couplers on the F/E of the vehicles in a consist and through inter-car connections of the married pair.. Control of the friction brake pressure shall be through electrical (ED brake) or / and pneumatic trainlines. The chosen control concept shall be safe in all operating conditions including train separation and shall be submitted to SMART for approval. **[CDRL 13-01]**

13.2 Service Brake

Service braking shall be controlled from the trainlined braking command signals. . The brake control units (BCU) shall calculate the required level of friction braking per truck, based on the trainline command signals, dynamic braking effort, wheel slide control status and load weigh signals. The primary service brake shall be the dynamic brake.

13.3 Thermal Capacity

The friction brake system shall have the thermal capacity to provide for five all friction brake stops from the maximum vehicle speed at the maximum vehicle load.

The friction brake system shall have the thermal capacity to provide continuous operation over the whole SMART alignment with a passenger loading at AW2. A speed limit of not less than 65 mph may be applied to prevent overloading the friction brakes.

The carbuilder shall provide thermal load calculations for the SMART alignment in normal blended operation at AW3 and abnormal operation with dynamic brakes cut out at AW2 loads. **[CDRL 13-02]**.

13.4 Dynamic Brake Interface / Blending

A dynamic brake signal from the propulsion system, proportional to the achieved dynamic braking effort shall be utilized by each BCU to modulate disc brake effort in response to the dynamic braking effort on that truck, such that the requested brake effort is provided regardless of the status of dynamic braking.

The dynamic brake shall be the primary brake and provide most of the brake power. The carbuilder shall provide a brake performance diagram, identifying the maximum dynamic brake effort as well as the total braking effort over the whole speed range for a vehicle load of AW3. **[CDRL 13-03]**

13.5 Emergency Brake

An Emergency Brake application shall be capable of being initiated by placing the master controller in the Emergency position, or energizing an Emergency Brake Valve located in the passenger compartment or from anywhere in the consist. An emergency brake command shall de-energize the EB trainline and dump the control pressure, initiating the emergency brakes on all vehicles in a train. Generator field or hydraulic transmission, motoring command, blending, jerk limitation and wheel slide protection shall be disabled. .

EB performance shall be as specified in section 2. **[CDRL13-04]**

13.6 Emergency Brake Valves

Emergency Brake Valves shall be installed in the passenger compartment and Operators Cab in accordance with 49 CFR 229.47. Each Emergency brake Valve shall be clearly labeled with the words EMERGENCY BRAKE VALVE. The location of Emergency Brake Valves shall be submitted to SMART for review and approval. (CDL 13-05)

13.7 Spring Applied Parking Brake

A spring applied parking brake system shall be capable of holding a train consist loaded to AW3 + 10% on a 3% grade indefinitely under all allowable wheel and brake conditions. The parking brake system shall apply in a fail-safe manner whenever the direction command is removed. A means to activate or deactivate the spring applied parking brake shall be located in the Operators Cab as required in Section 5. The spring applied parking brake arrangement and grade calculations shall be provided to SAMRT for review and approval. **[CDRL 13-06]**

The parking brake control signal shall be configured to release the parking brakes when energized.

13.8 Cleaning Pads

At least two axles of a car shall be equipped with thread cleaning pads to improve the shunting of the rails for grade crossings and other track circuits. Cleaning pads shall be applied whenever a brake command is given. Provisions shall be provided to activate the cleaning pads also in motoring and coast at a reduce pressure. This function shall initially be disabled.

13.9 Brake Discs

Brake discs shall be replaceable by bolted connections, not requiring truck or axle removal from the vehicle, or pressing off of any axle components.

13.10 Brake Pads

Brake pads shall be replaceable without disassembly of the brake caliper or other vehicle components

13.11 Sander System

A sanding system shall be provided that deposits sand immediately in front of the leading wheels of the motor trucks. Sand boxes shall be sealed and provide a volume of at least 50 liters. The aluminum or stainless steel boxes shall be sealed and easily accessible for filling.

Sanders shall be pneumatically operated and heated to keep the sand dry. The flow rate shall be adjustable initially set to 1lbs/min.

13.12 Load Compensation

The braking system shall automatically adjust the brake force to compensate for varying passenger loads. Weight sensing shall be independent for each truck. Weight signals shall be shared with the propulsion system. The load compensation scheme shall be provided to SMART for review and approval. **[CDRL 13-07]**

13.13 Friction Brake Propulsion Interlock

The friction brake system shall be interlocked with the traction system such that traction power for the entire train is removed if any friction brake remains applied on any truck in a train, including parking brakes, for more than 5 seconds after the application of tractive power.

13.14 Brake Cutout

The friction brake system shall include brake cylinder (as applicable) and service brake cut-outs for each truck. The BCO and SBCO cut-outs scheme shall be submitted to SMART for review and approval. **[CDRL 13-08]**

13.15 Air Compressor

Main reservoir pressure shall be trainlined.

Each car shall supply clean, dry, cool, oil-free air to its local brake system and, to the entire consist. The air supply system and reservoirs shall be sized to support the local married pair or car and one additional married pair or car of equal size, with an inoperable air supply system. The start of all air compressors in a consist shall be synchronized to avoid overloading a single compressor.

The air supply system shall be modular and interchangeable between vehicles. The system shall be service proven or built of service-proven components.

The air compressor and filter/dryer shall be operated by the 480VAC, 3-phase, auxiliary power supply

13.16 Controls

The friction brake system shall include microprocessor-based controls (Braking Control Unit, or BCU) on a per-truck basis. Each BCU shall independently interpret master controller and other signals from the controlling cab and apply the requested brake effort, augmented by the dynamic brake signal from the propulsion ECU.

Each BCU shall provide system status and fault logging, and shall connect to the vehicle data network. The BCU system status and fault logging scheme shall be submitted to SAMRT for review and approval. .**[CDRL 13-09]**

Emergency braking shall be initiated directly by hard-wired signals from the cab console and the control pipe pressure drop to all brake control valves, and sanding controls, and shall not be processed by the BCU, except for monitoring purposes.

13.17 CDRLs

13-01 Friction brake system overview components and operation

13-02 Friction brake system thermal capacity analysis

13-03 Brake performance diagram

13-04 Emergency brake performance diagram

13-05 Locations of Emergency Brake Valves

13-06 Park brake arrangement and grade calculations

13-07 Load weigh system description

13-08 BCO and SBCO cut out description

13-09 Description of BCU functionality, interface with vehicle data bus, diagnostic features etc.

14 COMMUNICATIONS EQUIPMENT

14.1 General

The car Communication Package will be comprised of on board train radios, public address (PA), automatic announcement system (AAS) and passenger emergency intercom (PEI). It shall function with a passenger information and automatic announcement system, which includes exterior and interior destination signs. All communication components shall have a proven track record in public transit.

The communications system shall permit the train crew to make announcements, page passengers, and other train crew members. It shall:

- Permit two-way radio communication between the train crew, operator, other trains, and wayside installations.
- Permit two-way intercommunication, cab-to-cab, between any two or more communication panels within the train, or consist.
- Accommodate recorded or digitized messages for announcements, or other passenger information, as required per 49 CFR 38.
- Enable announcements to be interfaced with the interior destination signs for visual broadcasting.
- Passengers shall have the capability to communicate with the train crew members via the Passenger Emergency Intercom.
- Include capabilities to record all PA announcements made on the vehicle.
- Provide for a transfer of data between the train and wayside installations, using a wireless data link.

The communications system functions that require data transfer between cars, or components within a car, shall utilize an Ethernet network.

The communication controls shall incorporate a local diagnostic and test system that interfaces with the monitoring and diagnostic system (MDS) and portable test units (PTU) described in Section 11.

The communication package shall operate efficiently and effectively for all possible consist combinations without adjustment. An inoperable communication system on one or more cars in a consist shall not adversely affect the operation of the communication systems on the rest of the cars in the consist.

The communication package equipment shall not pose any health hazard to the public, passengers, and train crew. It shall be in strict compliance with all applicable FRA, ADA, AAR, FCC, State, Federal, guidelines and regulations. This shall include compliance with 49 CFR 220, Railroad Communications.

Exposure to RF emissions shall conform to IEEE C95.1, Table 2. The equipment shall be in accordance with IEEE STD 1477, latest revision, where the requirements do not conflict with the Technical Specification. Refer to Section 11 for electronic control, software and MDS design requirements.

Details of the design, hardware, software, equipment arrangement, location and usage of the Communication Package shall be submitted to SMART for review and approval **[CDRL 14 – 1**].

14.2 Public Address

The Public Address (PA) System shall provide the function of making audio announcements, via the interior and/or exterior speakers. Audio announcements may be made by either the train crew or the automated passenger information system. Train crew announcements shall override automated announcements. The PA system shall provide, clear intelligible audio, with a constant audio level regardless of the position of the audio source within the train, incorporating an automatic volume adjustment feature to compensate for ambient noise conditions. The PA system shall include microphones, amplifiers, speakers, associated wiring and circuits.

A boom style or gooseneck, noise-cancelling, dynamic, microphone shall be provided in each cab, usable for all PA, cab-to-cab, and PEI modes. The PA amplifier power shall be sufficient to drive interior and exterior speakers at maximum levels, simultaneously, without audible distortion.

A minimum of eight internal speakers shall be installed per car, providing an even, comfortable, sound distribution, and intelligible audio, at all seating locations, within 3 dB, under all operating conditions. Four speakers, suitable for exterior operation, shall be mounted on the exterior of the car, two per side, near the side doors. All speakers shall be arranged to eliminate feedback from any audio input source. The location and number of speakers shall be subject to the approval of SMART **[CDRL 14 – 2]**

The frequency response of all audio circuits, from signal origin to output signal at the speaker shall be 150 Hz to 6 kHz, ± 1 dB at all power levels. Total harmonic distortion of all circuits, without compression circuits, shall not exceed 1% at 1 kHz, full output.

The PA system, from the input of the microphone (or digitized audio messages) to the output of the speakers, shall have a 90% intelligibility rating when tested according to ANSI S3.2, latest revision, “Method for measuring the intelligibility of speech over communications system.”

14.3 Automatic Announcement System

An Automatic Announcement System (AAS) shall be provided to inform passengers of the approaching station, current station, and any other audio or visual information that SMART wishes to make. The information shall be given in the form of PA announcements and interior visual displays.

Station announcements, audio and text, shall be triggered automatically, and based on GPS position. A backup position shall be calculated using the vehicle speed in case the GPS signal is lost. Interior displays shall indicate the next station stop in a timely manner.

The control of all destination signs, audio announcements, and AAS controls, shall be interfaced using an Ethernet network, using a mesh topology, where a single point network failure shall not cause the system to fail.

14.4 Automatic Announcement System Control Panel

The Automatic Announcement System control panel shall control the following features:

- Enter the Train or route number
- Initiate special and public messages (audio and text)
- Adjust PA volume
- Silence external PA speakers
- Temporarily pause the automatic station identification system
- Allow downloading/uploading of sign database and recorded message files from a PTU and via remote wireless link.

14.5 User Programming, Message Formats

The system shall have enough capacity to store 100 routes, with a minimum of 100 stations for each route, 10 audio, and 10 text messages per station, and no less than 50 special messages, audio and text, directly selectable at the AAS control panel. Storage for audio messages shall assume at least 30 seconds per message. Text messages shall assume 64 characters each. Message capacity shall depend only on available memory. There shall be no inherent limitation built into the control software or algorithms. Message data shall also be up-loadable via a common data protocol and connector, such as Ethernet.

Audio messages shall be encoded and stored in a common, publicly available, digital format such as MP3. Audio sample rates and compression levels shall be chosen for excellent human voice and good music fidelity at the speaker. Audible noise or distortion shall not be present in the message. The audio recording and playback processes shall be submitted to SMART for review and approval **[CDRL 14 – 3].**

Each audio and text message shall be stored with, or linked to, related information identifying the message type, destination device addresses, distance-on-route for automatic message triggering, and similar parameters, all of which shall be programmable by SMART.

All audio messages shall be recorded in English and Spanish using an approved human voice and shall be submitted to SMART for review and approval **[CDRL 14 – 4].**

A complete set of equipment for the recording and modification of the visual and audible messages shall be provided. The system shall be comprised of standard COTS equipment. This equipment shall include everything required to reprogram the on-board systems with new messages.

14.6 Destination Sign System

An electronic destination sign system shall be installed on each car, complying with all requirements of ADA, 49 CFR 38, IEEE - 100, 1473, 1477, and 1482.

All cars shall have a minimum of 6 interior and 5 exterior signs. The internally-viewed signs shall be installed in wall panels at approved locations, shall be interchangeable, and display AAS passenger information. Externally-viewed side signs shall be located, one near each side entry door, and one above the cab windshield, displaying destination or route information. Alternate locations may be submitted for approval by SMART.

Visual display signs shall be either, single-line, dot-matrix LED or back-lit LCD displays, capable of scrolling a message, as approved by SMART **[CDRL 14 - 5]**. The signs shall be, minimum, single-line displays 15 alpha-numeric characters. Interior signs shall have a minimum character height of 3 inches, while exterior signs shall have a minimum character height of 5 inches. The visual display signs shall be mounted behind polycarbonate windows, and shall be vandal-proof.

14.7 Passenger Emergency Intercom

A passenger emergency intercom system shall allow two-way communications between individual passengers and the operator. Each car shall have, at minimum, two PEI stations, one at each doorway or vestibule.

The PEI panel shall be vandal proof and include:

- A flush mounted microphone and intercom speaker, behind a perforated vandal proof grill.
- An EMERGENCY CALL pushbutton for PEI activation.
- A green visual annunciator to indicate activation and acknowledgement.

Operating instructions shall be provided adjacent to the panel in photo luminescent material per APTA STD SS-PS-001-98, and shall read as follows:

- PRESS BUTTON
- RELEASE

- WAIT FOR STEADY LIGHT

Once the system is activated by a passenger, further operation on the part of the passenger shall be hands-free and shall remain under the control of the operator/train crew. The crew member shall have the ability to control the conversation.

14.8 GPS

A GPS system shall be provided for use by the AAS and MDS system, and other systems on the car that require position and time information. The GPS shall provide the vehicle/train time which shall be passed on to all relevant vehicle control electronics.

The GPS antenna shall mount on the roof, or other location, optimized for satellite access. The antenna location shall be coordinated with the radio antenna to avoid interference.

14.9 Train Radio

Radios shall be commercial units functionally compatible with the existing SMART radio system and those of local railroads. The radios shall be integrated into the cab console. Radio type, function, and location shall be reviewed and approved by SMART **[Included in CDRL 14 – 6]**.

14.10 Closed Circuit Television

Each car shall be equipped with a Closed Circuit Television (CCTV) consisting of 5 color cameras, DVR, CCTV controller and other ancillary equipment, as required. The digital surveillance equipment shall be connected using an Ethernet network, independent of the Vehicle Control Network. The CCTV network shall use a mesh topology, where a single point network failure shall not cause the system to fail.

Each Car shall be equipped with enough interior color surveillance cameras mounted to provide complete coverage of the passenger area, including all door openings looking out to the platform. An additional color camera shall be mounted in the cab to provide a wide angle front view, covering the area in front of the vehicle. Two cab-forward cameras shall be used if deemed necessary by SMART to cover a 180-degree arc in front of the cab. All cameras shall be connected to a digital video recorder (DVR), using the CCTV Ethernet network.

The DVR shall have hot-swappable non-volatile memory storage (hard-disk), with a simple plug-in arrangement for playback on a standard laptop PC. Recording shall be active whenever the vehicle auxiliaries are turn on.

The DVR shall be capable of storing uninterrupted video streams per, California Law 53160, 53161 and 53162, which requires storing of video streams for not less than one year.

Each camera shall record audio and video, have a minimum resolution of 1.3 megapixels (1280×1024) and use MPEG-4/MJPEG compression. The camera shall have a maximum frame rate of at least 30 fps using MPEG-4 and 15 fps using MJPEG compression. The frame rate and bandwidth for each camera shall be controllable, using the CCTV controller.

The CCTV system shall provide automatic data transfer between the car and wayside storage installations using a wireless data link; the wireless data link may be external to the CCTV system.

The camera locations and control arrangement shall be subject to approval by SMART **[CDRL 14 – 7].**

14.11 Onboard Public World Wide Web Access, Wireless Data Link

Details to be further defined during design reviews by SMART and service provider.

14.12 Modem and Antenna

Details to be further defined during design reviews by SMART and service provider.

14.13 WIFI IP Router

The Supplier shall provide a high performance COTS mobile access IP router of rugged design (such as the CISCO 3200/Parvus DuraMAR) that is specifically optimized for use in vehicles utilized by public transportation agencies, and shall meet or exceed the requirements listed in MIL-STD-810F. The IP router (WIFI.R) shall support the following design attributes:

- Simultaneous usage of UDP/IP and TCP/IP transmission protocols
- User-configurable data packet transmission priorities based on Quality of Service (QoS)
- Ethernet Ports with IP67 D-coded M12 Connectors
- Support of advanced IP services such as Virtual LAN, Discovery Protocol, Policy routing, IP Multicast, etc.
- Firewall protection/access rights

14.14 Inter-Car Connections

Communications and passenger information circuit connections between cars shall be made through the electrical coupler at each F/E and through inter-car jumpers at the B/E.

Communications and passenger information circuit connections between body sections of a car shall be through separately shielded cables with individually shielded audio pairs or data pairs.

Connectors shall be heavy duty waterproof twist-lock type with gold plated contacts.

14.15 CDRLs

14.1 Communication package design details

14.2 Location and number of speakers

14.3 Audio recording and playback process

14.4 Human voice samples

14.5 Destination sign visual displays

14.6 Radio type, function and location

14.7 CCTV locations and control equipment arrangement

15 OPERATIONAL SAFETY SYSTEMS

15.1 General

Each married pair shall be equipped with a vital communication based Positive Train Control (PTC) System compliant with the Rail Safety Improvement Act of 2008 and 49 CFR 236. Additionally an Alerter and Event Recorder System compliant with 49 CFR 238 and 49 CFR 229 shall also be provided. Provisions shall also be included for future retrofitting of an overlay Automatic Train Control System.

15.2 Positive Train Control

The PTC system shall include but not be limited to an on-board microprocessor, data radio, a vital onboard display unit in each cab, GPS, cab make-up and brake system interfaces, various antennas's and associated hardware. Space shall be allocated for this equipment within the vehicle. The on-board display unit shall be located in the cab, preferably adjacent to the windshield, but not obstructing the operator's normal forward view.

15.3 Alerter System

The Alerter shall consist of both visual and unique audible alarms and shall monitor the Train operator's movements to determine enforcement requirements.

The alerter system shall monitor absence of a defined action by the operator followed by alarm signal and penalty brake application. The system shall be reset by detection of defined action by the Train Operator. In accordance with 49 CFR 238.237, the Car Builder shall submit the system design criteria for alerter timing to SMART for review and approval. **[CDRL 15-1]** The location of the audio and visual alarms shall be reviewed as part of the cab design.

15.4 Event Recorder System

The Event Recorder system (ERS) shall consist of a main recorder unit, crash hardened memory module, airbrake manifold and any other interface modules required to receive required monitored signals from other systems on the train. One ERS shall be provided on each married pair. The ERS shall be a stand-alone device, independently operated, and powered from the Car's low voltage power supply. The ERS shall be solid-state microprocessor-based unit. The data storage memory module shall be FRA- and IEEE-compliant as specified in this Section. The system shall include any required sensors, transducers, pressure switches, power supplies, and isolation module.

The Event Recorder shall operate continuously as long as battery trainline power is at a sufficient voltage level to operate the event recorder unit.

The Event Recorder shall record, at minimum, the data elements shown in Table 1.

Table 1 – Event Recorder Data Elements

Data Elements/Source/Type			
No.	**Signal Name**	**Signal source**	**Type**
1	Distance	Derived	
2	Time/Date/Year	Internal	Default
3	Direction/Forward	Trainline	Digital
4	Direction/Reverse	Trainline	Digital
5	Master Controller Position	Handle Position Switch 1	Digital
6	Master Controller Position	Handle Position Switch 2	Digital
7	Master Controller Position	Handle Position Switch 3	Digital
8	Master Controller Position	Handle Position Switch 4	Digital
9	Master Controller Position	Handle Position Switch 5	Digital
10	Brake Pipe Pressure	Air Brake Monitoring	Analog
11	Brake Cylinder Pressure	Air Brake Monitoring	Analog
12	Dynamic Brake	Control Stand	Analog
13	Main Reservoir Pressure	Air Brake Monitoring	Analog
14	Emergency Brake Application (master controller)	Air Brake Monitoring	Digital
15	Emergency Brake Application (other)	Air Brake Monitoring	Analog
16	Brakes Applied Summary Trainline	Air Brake Monitoring	Analog
17	Brakes Released Summary Trainline	Air Brake Monitoring	Analog
18	Headlights	Switch Contact	Digital
19	Auxiliary Light	Switch Contact	Digital
20	Horn Activation	Switch Contact	Digital
21	Car Unit Number	Local ID Plug	Digital
22	Traction Current	Traction Current Monitoring	Frequency (4)
23	Tractive Effort	Local Signal	Analog (4)
24	Alerter Acknowledgement	Switch Contact	Digital
25	Alerter Penalty	Local Signal	Digital
26	Alerter Alarm	Local Signal	Digital
27	Door Closed Summary Trainline	Trainline	Digital
28	Parking Brake	Local Switch	Digital
29	Related PTC functions (5 to 6 anticipated)	Local signal	Digital
30	Provisions for future ATC functions (4 TO 5 anticipated)	Local signal	Digital

In addition the ERS shall have provision for:

1. Five spare isolated digital channels;
2. Four spare analog channels; and
3. Two spare frequency channels.

15.5 Provisions for Future Automatic Train Control System

Provisions for an Automatic Train Control System shall be provided on each car and/or married pair as required. These provisions shall include but not be limited to the following components: microprocessor, conduit, various brackets including track receivers, wiring interface points, circuit breakers, by-pass switch, speed sensors. separate and distinct alarm, spare event recorder channels, ATC operative interior and exterior indicating lights, overspeed indicating light, adaptability with the PTC on-board display and interface with Monitoring and Diagnostic System (MDS). Drawings indicating the provisions for future installation of ATC equipment shall be provided to SMART for review and approval. **[CDRL 15-2]**

15.6 CDRL's

15-1 Alerter Timing Design Criteria

15-2 Drawings indicating provisions for future installation of ATC equipment

16 SYSTEM SAFETY REQUIREMENTS

16.1 General

The Contractor shall design, build, test and certify the DMUs so they achieve acceptable safety for passengers, persons nearby, and employees, under normal operating conditions and in the event of equipment failures. The Contractor shall insure that all safety aspects have been considered and resolved for each individual system and for the integrated systems in the DMUs.

16.1.1 System Safety Program

The Contractor shall implement a System Safety Program including a robust Hazard Management process per MIL-STD-882C or equivalent. The System Safety Program shall cover hardware safety, software safety, fire safety, electromagnetic compatibility, security, and integration of safety requirements and hazard resolution between the DMUs and other SMART systems including train control, trackwork, stations, and maintenance facilities.

The Contractor shall provide a System Safety Program Plan (SSPP) **[CDRL 16-01]** within 60 days after NTP. The SSPP shall specify the System Safety Program scope, objectives, activities and schedule, deliverables and reporting, identity and organization of program participants, and methods and techniques by which Contractor will meet the SMART system safety requirements. The SSPP shall define system safety program interfaces with other DMU project elements such as project planning and management, scheduling, supplier control, reliability and maintainability, manuals and training, technical requirements, DMU and subsystem design, software development and quality assurance, analysis, and test.

The Contractor's SSPP shall incorporate requirements from 49 CFR 238 Subpart B (specifically 49 CFR 238.105) and 49 CFR 236 subparts H and I as applicable to electronic hardware and software used to control or monitor safety functions in passenger equipment.

The Contractor shall provide all necessary documentation and support SMART in application of PTC Safety Certification in accordance with 49 CFR 236 requirements including an independent 3rd part review. **[CDRL 16-02]**

The Contractor shall conclude the DMU System Safety Program with a Safety Certification task, described below.

16.1.2 System Safety Acceptance Requirement

Table 16.1 shows the specific safety acceptance criteria for the SMART DMUs.

Table 16.1 – System Safety Program Acceptance Criteria

Event Frequency	Hazard Event Severity			
	I **Catastrophic** Death or system loss	**II** **Critical** Severe injury or major system damage	**III** **Marginal** Minor injuries or minor system damage	**IV** **Negligible** Less than minor injury or system damage
A – Frequent MTBE < 1E3 hrs	Unacceptable	Unacceptable	Unacceptable	OK
B – Probable 1E3 hrs < MTBE < 1E5 hrs	Unacceptable	Unacceptable	Unacceptable	OK
C - Occasional 1E5 hrs < MTBE < 1E7 hrs	Unacceptable	Unacceptable	Notice Required	OK
D – Remote 1E7 hrs < MTBE < 1E9 hrs	Notice Required	Notice Required	OK	OK
E – Improbable 1E9 hrs < MTBE	Notice Required	OK	OK	OK

Table 16.2 defines the hazard severity categories for the SMART DMU system safety program.

Table 16.2 – Hazard Severity Categories		
Description	**Category**	**Mishap Definition**
Catastrophic	I	Death or System loss
Critical	II	Severe injury, severe occupational illness, or major system damage
Marginal	III	Minor injury, occupational illness or system damage
Safe	IV	Less than minor injury, occupational illness, or system damage

Table 16.3 defines the hazard frequency levels for the SMART DMU system safety program.

Table 16.3 – Hazard Frequency Levels			
Description	**Failure Rate Limits (per hour)**	**Level**	**Level Definition**
Frequent (1/day)	1E-1	A	Likely to occur frequently
Probable (1/month)	1E-3	B	Will occur several times in the life of the System.
Occasional (1/year)	1E-5	C	Likely to occur sometime in the life of the System.
Remote (1/30 years)	1E-7	D	Unlikely but possible to occur in the life of the System.
Improbable (less than 1/30 years)	1E-9	E	So unlikely, it can be assured occurrence may not be experienced

16.1.3 Failure Induced Hazards

Vehicle equipment and systems shall be designed and constructed to revert to safe modes under failure conditions. The Contractor shall employ high quality components, proven systems, redundancy, checking devices, and other techniques to accomplish this goal.

Vehicle systems, the failure of which could result in injury to a person or damage to the vehicle, shall conform to both of the following design principals:

- The failure of a single device shall not result in a permissive condition
- An undetected failure of any device shall not permit a subsequent device failure to result in a permissive condition.

The term ‘failure’ includes both the initial device failure and all consequential device failures caused by the initial failure.

The term ‘device’ includes any component, subsystem, or system, whether electrical or mechanical, pneumatic or hydraulic.

The terms ‘restrictive’ and ‘permissive’ relate to potential system responses, which result in either a more safe or less safe condition, respectively, such as: stop versus proceed, a lower speed versus a higher speed, deceleration versus acceleration, brakes applied versus brakes released, actuation of alarm versus no actuation of alarm, etc.

Systems shall conform to the safety design principals by one or both of the following methods:

- The utilization of vital devices, that is, devices with known, guaranteed-by-the-manufacturer failure modes, such as signal grade relays, combined in circuits in such a way that the requirements of this section are met
- Independent channels with independent checking of each. All channels shall indicate a permissive state in order for the controlled system to achieve a permissive state. Failure in any channel shall not affect any other channel, or force the system into a permissive state, unless other actions are required by other parts of this Specification. Differences in state between channels shall be alarmed and shall force a restrictive state on the system.

Equipment failures which result in an indication of danger, whether or not actual danger exists, shall be considered to have occurred in a safe manner. Conversely, a failure which results in an indication of safety when, in fact, a dangerous condition may exist, shall be considered unsafe.

16.2 Hazard Analyses

The Contractor shall perform a robust hazard analyses. Analyses shall demonstrate that the vehicle conforms to the requirements of this Specification, applicable federal, state and local safety regulations, and that all identified hazards are either eliminated or reduced to levels of risk acceptable to SMART. The Contractor shall adjust or amend all hazard analyses as the vehicle design and construction progresses.

The Contractor shall select analysis methods as appropriate for the system under evaluation and the hazard severity, subject to approval by SMART. The Contractor shall be prepared to demonstrate, by test, the validity of any portion of all analyses. Hazard analysis shall be updated frequently during design and prior to the start of each of the testing programs identified in Section 18.

The Contractor shall use standard failure and safety analysis methods and experiential failure rates for components wherever possible.

The Contractor may offer existing hazard analyses of like equipment operating under like conditions in lieu of performing a complete analysis of proposed equipment, subject to SMART's approval.

Hazard analyses shall include the following:

- Preliminary Hazard Analysis (PHA)
- Fault Tree Analysis (FTA)
- Failure Modes, Effects, and Criticality Analysis (FMECA)
- Sneak Circuit Analysis (SCA)
- Operating Hazard Analysis (OHA)

16.2.1 Preliminary Hazard Analysis

The Contractor shall perform a Preliminary Hazard Analysis **[CDRL 16-03]** for all Hazard Severity Category I, II, and III hazards. The PHA is due within 90 days after NTP, in time for the Preliminary Design Review.

The PHA shall be an initial assessment of hazards which identifies potential provisions to control hazards, consistent with MIL-STD-882C Task 202. The PHA shall consist of a general description of the hazard; assessment of potential causes and effects of the hazard, including an estimation of the hazard severity; and a list of potential corrective actions that the Contractor, its suppliers, and other project participants might take to eliminate or control the hazard.

16.2.2 Fault Tree Analysis

The Contractor shall perform a Fault Tree Analysis **[CDRL 16-04]** for all Hazard Severity Category I and II hazards. The initial FTA is due within 180 days after NTP.

The Contractor shall perform the FTA consistent with the Fault Tree Handbook, NUREG-0492, published by the U.S. Nuclear Regulatory Commission. The Contractor shall develop a fault tree for each top-level Category I and II hazard identified in the PHA, investigating all significant causes, conditions, and mitigations related to the hazards.

The Contractor shall tabulate all bottom-level events from the fault trees in a Basic Events Table. The Basic Events Table will include:

- Event ID number
- Event description
- Event frequency
- Event responsibility
- Remarks, including cross-references to FMECA and OHA items
- Action required

16.2.3 Failure Modes, Effects, and Criticality Analysis

The Contractor shall perform a FMECA **[CDRL 16-05]** for all equipment in all DMU systems. The initial FMECAs are due within 180 days after NTP.

The FMECAs will systematically analyze each potential equipment failure mode of each equipment item, and for each failure mode, determine the hazard severities, failure rate, failure effects, means of failure detection, and failure management strategies. The Contractor shall update and review the FMECAs on a periodic basis including in conjunction with the Final Design Review, to ensure that necessary design modifications are made and that these do not introduce new safety-critical failure modes.

Critical hazardous events identified in the FMECAs will show as basic events in the fault trees.

FMECA data shall be a key input to the maintenance manuals and training program.

The FMECAs shall provide:

- Identification of single failure points critical to proper DMU performance and human safety
- A basis for selecting the location and coverage of performance monitoring and fault sensing devices and other built-in automatic test equipment
- Design engineers with a method of selecting a design with a high probability of operational success and safety
- Early visibility into potential DMU interface problems
- A list of possible failures which can be ranked according to their category of effect and probability of occurrence
- Early criteria for test planning
- A tool which helps evaluate proposed design, operational, or procedural changes and their impact on DMU performance or safety.

16.2.4 Sneak Circuit Analysis

The Contractor shall perform a Sneak Circuit Analysis **[CDRL 16-06]** on distributed relay circuits of the DMUs, such as door control trainlines, propulsion and brake control trainlines, and cab control trainlines. The initial SCA is due within 180 days after NTP.

The SCA will investigate the effects of unintended circuit paths in the appropriate circuits. The analysis will probe only unintended circuit effects, not component failure effects. The SCA may be presented in an appropriate text or tabular format, and will ensure that distributed relay circuits do not have hazardous, unintended effects or operating conditions.

16.2.5 Operating Hazard Analysis

The Contactor shall perform an Operating Hazard Analysis **[CDRL 16-07]** addressing hazard relationships of people and the DMUs. The initial OHA is due within 180 days after NTP.

The OHA will cover operating and maintenance activities. It will document hazards identified in the PHA and analyzed in the FTA which are associated with actions by operating and maintenance personnel. The OHA is a type of Subsystem Hazard Analysis (SSHA).

Critical hazardous events identified in the OHAs will show as basic events in the fault trees.

OHA data shall be a key input to the maintenance manuals and training program. An important product of the OHA will be a list of recommended operating and maintenance procedures associated with the DMUs which SMART must perform to maintain train safety and to eliminate and control hazards.

16.3 Fire Safety

All materials used in the construction of the car shall meet the requirements of NFPA 130 2010, Chapter 8, 49 CFR 238.103 and 49 CFR 238.103 Appendix B.

16.3.1 Fire Safety Analysis

The Contractor shall provide a Fire Safety Analysis **[CDRL 16-08]** as required by 49 CFR 238.103(c). The preliminary FSA is due within 60 days after NTP. SMART must review and approve the preliminary FSA before The Contractor begins production on the vehicles. The final FSA is due by 30 days after acceptance of the final DMU.

The Contractor shall include written procedures for the inspection, testing and maintenance of fire safety systems and fire safety equipment in the maintenance manuals.

16.3.2 Flammability Tests

The Contractor shall submit certified copies of Flammability and Smoke Emission Test Reports **[CDRL 16-09]** for all materials which are subject to specific fire safety requirements and guidelines. The Flammability Test Reports are due within 180 days after NTP.

The Contractor shall perform Fire Safety type tests as follows:

- Flammability and Smoke Emission per 49CFR238.103
- Floor Assembly Fire Resistance per ASTM E119 **[CDRL 16-10]**
- Emergency Egress Tests for Passenger Areas, Toilet, and Cab **[CDRL 16-11]**

The floor structural assembly shall meet a 30 minute minimum endurance rating in accordance with ASTM E119. The ceiling structural assembly shall meet a 15 minute minimum endurance rating in accordance with ASTM E 119 if it contains equipment that operates at voltages higher than 600 V.

All materials used in the cars shall be selected to minimize combustion and propagation of fire both inside and outside the DMUs. All materials used in the cars must be in compliance with FRA Regulation 49 CFR Part 238, Section 238.103.

All materials used in car construction must be tested for the emission of toxic gases during combustion using the NBS Smoke Chamber, bellows pump, and the appropriate Draeger tubes for the gases involved. The tests are to be run in the flaming mode, with sampling done after 240 seconds. The test reports must show the maximum concentration (ppm) for each of the following gases:

- Carbon Monoxide (CO)
- Sulfur Dioxide (SO 2)
- Hydrogen Cyanide (HCN)
- Carbon Dioxide (CO 2)
- Hydrogen Chloride (HCl)
- Nitrogen Dioxide (NO 2)

16.4 Software for Safety-Critical or Vital Systems

16.4.1 General

Section 11 identifies general software development documentation requirements. Section 20 identifies general software quality assurance requirements. This section identifies additional requirements for all DMU software identified as vital or safety-critical.

The Contractor shall conduct a Software Safety Program for all vital or safety-critical software applications **[CDRL 16-12]**. Software Safety Program elements shall include:

- Software Program Management Plan (SPMP)
- Software Quality Assurance Plan (SQAP)
- System Functional description (SFD)
- Software Requirements Traceability Matrix (SRTM)
- Software Development Plan (SDP)
- Software Requirements Specification (SRS)
- Software Hazard Analysis (SHA)
- Software Design Documentation (SDD)
- Software Module Requirements Specification (SMRS)

- Software Verification and Validation Plan (SVVP)
- Software Verification and Validation Report (SVVR)
- Software Configuration Management Plan (SCMP)

16.4.2 Software Hazard Analysis

The Contractor shall perform a Software Hazard Analysis **[CDRL 16-13]** for all vital or safety-critical software. The initial SHA is due within 180 days after NTP.

The SCA will identify, evaluate, and eliminate or mitigate software hazards by means of a structured analytical approach that is integrated into the software development process. The SCA may include PHA, fault tree, fault hazard analysis, software checklist, Petri Net Analysis, and/or other methods, as approved by SMART.

16.4.3 Safety Certification

The Contractor shall develop a Hazard Resolution Report **[CDRL 16-14]** to track completion of the DMU System Safety Program activities and resolution of all identified Category I, II, and III hazards. The initial HRR is due within 240 days after NTP.

The HRR will track completion of mitigations of DMU hazards using a table derived from the FTA Basic Events Table and the OHA. The HRR hazard item tracking will include all items related to Category I, II, and III hazards identified in the FTA, OHA, FMECA, and other analyses such as EMI Safety Analysis, Fire Safety Analysis, Software Safety Analysis, as applicable. The table will identify each hazard's source analysis and ID number for traceability.

A summary table in the HRR will summarize the System Safety Program status, describe issues and approach, identify any open items, and provide conclusions. The Contractor shall update the HRR monthly after the initial submittal.

When the HRR Summary Table indicates all System Safety Program tasks are completed and approved by SMART, and that all identified Category I, II, and III hazards are satisfactorily resolved or controlled, the Contractor shall provide a Certificate of Safety **[CDRL 16-15]** in a format approved by SMART. The HRR will serve as the summary and directory of required supporting documentation, and will verify that each DMU hazard is controlled to the level required by SMART. The safety certification will reference the HRR, and the HRR references and identifies corresponding safety analyses, CDRLs, and other documentation.

16.5 Vehicle Safety Provisions

16.5.1 Emergency Equipment

Each car shall have emergency equipment and a first aid kit in compliance with 49 CFR 239.101 and SMART emergency preparedness policy.

16.5.2 Markings and Emergency Signage

All interior and exterior markings, decals and labels shall conform to the following:

- The Contractor shall clearly and permanently label (no decals) or tag each air line, hose, and valve; each electrical jumper, breaker, and receptacle; each electrical box, locker, and panel; each equipment box, locker, and compartment; and each item inside each box, locker, panel, and compartment. The labels shall be made from stainless steel. Labels and tags shall be applied proximate to the item when the label or tag is not part of the item assembly and the item is subject to replacement during unscheduled or scheduled maintenance. Labels and tags shall be affixed with mechanical fasteners.
- Decals for the various system functions and instructions shall be applied where applicable. All decals shall be edge sealed.
- Permanent metal "Danger - XXX Volts" tags to warn of voltages above battery voltage and other warning tags shall conform to FRA regulations and ISO-3864. Self-adhering tags shall not be utilized. Metal tags and their fasteners exposed to electrical equipment shall be covered with insulating paint.
- Embossed or intaglio metal tags shall be provided to identify all electrical and mechanical (including valves) components. Plastic, self-adhering tags shall not be utilized.
- Labels which certify that each car has been fully equipped in accordance with FRA Glazing Requirements, 49 CFR 223, shall be riveted in place by the Contractor. The labels shall be in plain view from inside the passenger compartment and by the cab.
- A metal letter "F", ¼ inch thick by three inches high, shall be permanently affixed to each side of the car, below the operator's compartment windows.
- Permanent metal "No Smoking" placards shall be mounted in the operator's compartment and in the toilet room. The placards shall be a stainless steel plate with photo-etched, paint-filled, black letters.
- Interior "No Smoking", "Emergency Exit" and "Caution" signs, and other permanent directional or advisory signs for passengers and/or crew members, shall be as directed by the Engineer.
- ADA-compliant “Priority Seating” signs shall be provided in the appropriate areas.
- Signage and locators showing the location of emergency exits and instructions on their operation shall be provided in each car per 49 CFR 239.113. Both doors and windows shall be marked. Low-location exit path marking shall be in compliance with APTA SS-PS-004-99 latest Rev., “Standard for Low-Location Exit Path Marking”.

- All interior emergency signage shall be produced on strontium aluminate-based, photo luminescent material to facilitate reading under adverse lighting conditions. After a charging period of 30 minutes under normal interior lighting conditions, the material shall remain luminescent for a period of 150 minutes, minimum. Interior emergency signage shall be in compliance with APTA SS-PS-002-98 latest Rev., "Standard for Emergency Signage for Egress/Access of Passenger Rail Equipment."
- Each car shall be equipped with retro-reflective exterior safety decals to assist emergency personnel during rescue operations, in compliance with 49 CFR 238.114 and APTA SS-PS-002-98 latest Rev., "Standard for Emergency Signage for Egress/Access of Passenger Rail Equipment." At minimum, all emergency exits, both doors and windows, shall be marked.
- All decals provided for passengers shall have raised lettering and Braille for the visually impaired.
- The markings on all stainless steel labels shall be sand etched or engraved to a depth of 0.008 inches, minimum, and filled with paint.

16.6 Contract Deliverable Requirements

Contract Deliverable Requirements List	
16-01	System Safety Program Plan
16-02	Positive Train Control (PTC) Safety Certification Data
16-03	Preliminary Hazard Analysis
16-04	Fault Tree Analysis
16-05	Failure Modes, Effects, and Criticality Analysis
16-06	Sneak Circuit Analysis
16-07	Operating Hazard Analysis
16-08	Fire Safety Analysis
16-09	Flammability and Smoke Emission Test Reports
16-10	Floor Assembly Fire Resistance Test Report
16-11	Emergency Egress Tests for Passenger Areas, Toilet, and Cab Test Report
16-12	Software Safety Program Plan for all vital or safety-critical software applications
16-13	Software Hazard Analysis
16-14	Hazard Resolution Report
16-15	Certificate of Safety

This Acronym Table will be moved to Section 1

Acronyms	
SSPP	System Safety Program Plan
PHA	Preliminary Hazard Analysis
FTA	Fault Tree Analysis
FMECA	Failure Modes, Effects, and Criticality Analysis
SCA	Sneak Circuit Analysis
OHA	Operating Hazard Analysis
FSA	Fire Safety Analysis
MTBE	Mean Time Between Hazardous Event
SWHA	Software Hazard Analysis
HRR	Hazard Resolution Report
SPMP	Software Program Management Plan
SQAP	Software Quality Assurance Plan
SFD	System Functional description
SRTM	Software Requirements Traceability Matrix
SDP	Software Development Plan
SRS	Software Requirements Specification
SHA	Software Hazard Analysis
SDD	Software Design Documentation
SMRS	Software Module Requirements Specification
SVVP	Software Verification and Validation Plan
SVVR	Software Verification and Validation Report
SCMP	Software Configuration Management Plan

17 MATERIALS AND WORKMANSHIP

17.1 General

Materials and workmanship shall be in accordance with the requirements of Industry best practice standards and all Federal, State and local codes.

Material Safety Data Sheets (MSDS) shall be submitted for all materials, used in the fabrication of the cars **[CDRL 17-1]**. This requirement shall include lubricants but excludes non-hazardous metallic materials. Information shall be in a form compliant with ANSI Z400.1-1993.

17.1.1 Quality

The contractor's Quality Assurance (QA) Program shall assure that all aspects of the Contract are in conformance with the design, materials, and workmanship requirements provided in the Technical Provisions.

17.1.2 Standards

The following domestic standards and specifications shall define the materials for this Contract: Federal or Military Specifications or Standards, the Specifications of the Aluminum Association of America, AAR, AISI, ANSI, ASME, ASTM, AWS, FRA, IEEE, APTA Standards and Recommended Practices for Rail Passenger Equipment, NFPA 30 and others, as specified herein. Where other or foreign standards are proposed by the Contractor, the Contractor shall demonstrate that the proposed standards are the equivalent of the foregoing standards and specifications. The most recent standards and specifications applicable at the time of issuance of the Notice to Proceed (NTP) shall apply unless otherwise approved by SMART.

17.1.3 Marking

All materials intended for use on these vehicles shall be marked or stored so as to be readily identifiable and shall be adequately protected during handling and storage. Rejected material shall be clearly marked and stored in an area specifically designated for that purpose.

17.1.4 Cleaning Agents

A list of recommended cleaning agents shall be provided for all materials exposed to normal cleaning operations and shall be included in the maintenance manual **[CDRL 17-2].** The Contractor shall make every attempt to minimize the number of different cleaning agents proposed.

17.1.5 Prohibited Materials

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

- PVC
- Asbestos
- Cadmium (except for battery)
- Lead, all applications including in paint and coatings, except for electronics solder and diesel engine starting applications
- PCBs
- Carcinogenic materials as listed by current Publication of the American Conference of Governmental Industrial Hygienists (ACGIH)
- All CFC and HCFC compounds
- R-22 refrigerant
- Urethane foam
- Materials listed in 29 CFR Section 1910.9.

17.2 Joining and Fastening

Certain combinations of materials require particular care in joining to avoid the possibility of corrosion. Isolating and moisture-proofing materials in accordance with applicable industry practice, appropriate to the materials being joined, shall be employed at all times where these combinations exist. The Contractor shall design the vehicles to minimize the number of such combinations, and to minimize the accumulation of water, cleaning chemicals, and chemicals present in the environment, at or near combination joints.

All structural and safety related bolts shall be a minimum SAE Grade 5 or equivalent. A fastener is safety related if failures cannot be tolerated, that is, if even a single fastener fails there is a possibility of brake failure, derailment, or an accident. Where applicable, safety related fasteners shall comply with all of the requirements of 49 CFR 231 – Railroad Safety Appliance Standards.

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

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

Alternate fastener coatings are permissible if qualified by testing per ASTM B117 with no red rust or visible corrosion products after 96 hours of exposure.

Regardless of the coating's propensity for hydrogen embrittlement, each lot of high strength fasteners, including OEM plated zinc or yellow bolts (Grade 5 or

Metric Grade 8.8 or higher) shall be tested for hydrogen embrittlement in accordance with ASTM F519 or ASTM F606.

All safety related fasteners that are plated or chemically cleaned shall be demonstrated to be free from hydrogen embrittlement. A representative sample of actual production fasteners shall be tested by the OEM Contractor or a supplier following ASTM F519 or ASTM F606 wedge-test procedures. Test loads shall be a minimum of 80% of yield strength or proof load and held for a minimum of 168 hours. Any failures shall reject the entire lot.

Each lot of lower strength, non safety critical fasteners shall be tested for hydrogen embrittlement if the coating has the possibility of causing hydrogen embrittlement.

17.3 Welding

The Contractor shall be responsible for the quality of its welding and brazing as well as that of its suppliers and subcontractors.

All structural welding practices shall be according to requirements of the AWS D1.1, "Structural Welding Code – Steel;" AWS D1.2, "Structural Welding Code – Aluminum;" AWS D1.3, "Structural Welding Code – Sheet Steel;" AWS D1.6, "Structural Welding Code – Stainless Steel;" AWS D15.1, "Railroad Welding Code;" and the AWS Handbook. Requirements for cyclically loaded structures shall be applied. Cast steel welding shall be according to ASTM A 488/488M, "Steel Castings, Welding, Qualification of Procedures and Personnel." Resistance welding shall be in accordance with the latest revision of AWS D17.2. AWS D1.1 shall apply to steel of 1/8-inch and greater thickness. AWS D1.3 shall apply to steel less than 1/8-inch thickness.

Regardless of the governing codes, all Welding Procedure Specifications (WPSs) shall be fully qualified by test by the Contractor. Qualification shall be documented by Procedure Qualification Records (PQRs). Welders shall make only those welds for which they have been qualified. WPSs, PQRs, and records of welder qualification tests shall be made available for review upon request. In addition, machine and procedure qualifications for resistance spot welding shall be made available for review upon request.

Use of other welding methods, such as laser welding or friction-stir welding, are permitted provided that the methods have been demonstrated to be suitable for the application in question, performed in accordance with appropriate specifications and codes, and approved by SMART.

The Contractor shall use an AWS certified welding inspector (CWI) to visually inspect all structural welds of every car in accordance with AWS D1.1 acceptance criteria.

17.4 Stainless Steel

Stainless steel used in structural applications shall conform to APTA SS-C&S-004-98, “Standard for Austenitic Stainless Steel for Railroad Passenger Equipment.”

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

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

17.5 High Strength, Low Alloy (HSLA) Steel

High Strength, Low Alloy (HSLA) steel structural shapes, plates, and bars shall, as a minimum, conform to the requirements of ASTM A 588. Plate steel may alternatively conform to ASTM A 710, Grade A, Class 1, 2, or 3. General requirements for delivery of HSLA shapes, plates, and bars shall be as required by ASTM A 6.

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

Other high strength, low-alloy steels which meet or exceed the above minimum requirements may be used, provided their detailed specifications are submitted and approved as equivalent or better material for the proposed applications. All HSLA steels shall be applied according to their specification properties.

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

17.6 Structural Castings

The Contractor shall be responsible for selecting casting grade, composition, strength, and finishing. However, steel castings, used in the carbody structure and truck assemblies shall meet AAR Specification M-201 latest revision, Grade “B,” plus 2% nickel, minimum. These castings shall be heat treated to develop a minimum tensile strength of 75,000 psi, a minimum yield strength of 48,000 psi, elongation of not less than 25% in 2 inches, and reduction of area of not less than 50%. Also, steel castings used for coupler, drawbars, and anchors shall meet AAR Specification M 201, latest revision, Grade “C” or “E,” quenched and tempered.

17.7 Aluminum

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

All aluminum structural members shall be designed so that calculated stresses under the specified AW3 passenger load do not exceed the allowable stresses per APTA SS-C&S-015-99, "Standard for Aluminum Alloys for Passenger Equipment Car Body Construction". Proper allowance shall be made for the effects of fatigue, for column and plate stability effects, and for strength reduction at welded regions. Permissible fatigue stresses under the specified AW3 passenger load shall be established, with approval based on available relevant research data or on prototype testing under the variable load patterns expected to occur in service.

17.8 Elastomers

Elastomers shall be compounded and cured to perform satisfactorily in the environment specified in TP02. The elastomers shall have high resistance to ultraviolet radiation, weather, and all proposed car washing and other cleaning fluids. All elastomeric parts shall be resistant to ozone, oxidation, heat, oil, grease, and acid, and have the longest possible life consistent with the other characteristics specified.

The following elastomeric parts shall be of neoprene and shall have a minimum service life of 10 years, unless otherwise specified or approved:

- Glazing Rubber
- Door Seals
- Door Nosing
- Isolation Tapes/Pads
- Other parts exposed to the outdoor ambient environment

All elastomeric parts listed above shall be tested according to the latest revisions of the specified ASTM test procedures. The test specimens shall be cut out from the proposed material, and at least one tensile strength and elongation test and one accelerated aging test shall be made on the material used for each order. If the compound or cure, or both, are changed during the production of material for one order, at least one test of each type shall be made for each different batch.

When testing the 6-inch by ½-inch ASTM "dumb bell" type test specimen (or smaller size if the size of the part necessitates) by the methods specified in ASTM D 3182, D 3183, D 3190, and D 412, the tensile strength shall not be less than 1,500 psi and elongation shall be a minimum 350 percent. The tensile strength of the elastomer shall not be reduced more than 25 percent when subjected to accelerated aging by the methods specified in ASTM D 573 for a period of 96 hours in an air oven at 158ºF.

The ozone resistance of the elastomer shall be tested in accordance with ASTM D 1149 using an ozone concentration of 100 pphm, an exposure time of 100 hours at 100ºF, and a specimen elongation of 20 percent. The elastomer shall not exhibit any cracks during the test period.

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

17.9 Glazing Materials

The Contractor shall be responsible for the performance of all inspection and test requirements for glazing materials.

17.9.1 Safety Glass

Safety glass shall meet the requirements under Item 1, Table 1 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," and the requirements of 49 CFR 223 and 238, including impact and smoke and flame requirements.

17.9.2 Plastic Glazing

Plastic glazing shall meet the requirements under Item 4, Table 1, of the latest revision 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 material shall also meet the requirements of 49 CFR 223 and 238, including impact and smoke and flame requirements.

17.10 Rubber Floor Covering

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

At 68 degrees Fahrenheit, the rubber flooring shall bend 180 degrees around a 3/4-inch diameter mandrel without breaking, cracking, crazing, or showing any change in color. The rubber flooring material shall be fully homogeneous throughout and shall meet the requirements of ASTM F 1344.

17.11 Wood and Panels

17.11.1 Lumber

Lumber shall be thoroughly air seasoned or kiln dried before using, so as not to have a moisture content of greater than 12%. Lumber shall be dressed on all surfaces to full dimensions. Lumber shall be straight-grained, free from dry rot, knots, checks, and other defects which may impair its strength and durability or mar its appearance.

17.11.2 Plymetal

All plymetal panels shall conform to the following requirements:

Test Conditions	**Minimum Metal to Wood Average Shear Value (or 80% Wood Failure)**
Dry Shear	250 lbf/in²
Boil shear, 3 hr. boil, tested wet at room temperature	150 lbf/in²
Soak shear, 48 hr. soak wet at room temperature	150 lbf/in²
Creep or cold flow, under static load for 48 hrs., at room temperature	250 lbf/in²

17.11.3 Plywood

All plywood shall be manufactured to conform to the requirements of Grade – Structural I of the National Bureau of Standards Voluntary Product Standard (American Plywood Association) PS 1-95, and then stored under cover.

17.12 Honeycomb Panels

Aluminum honeycomb material shall be commercial grade meeting the requirements of MIL-C-7438G. Bonding shall be sufficient to develop the full strength of the honeycomb material.

Stainless steel-faced, stainless steel honeycomb panels shall be constructed in accordance with the requirements of MIL A 9067.

17.13 Melamine-Faced Aluminum

Melamine-faced aluminum panels shall be constructed by laminating melamine to aluminum sheets. The melamine-impregnated papers shall be directly molded to the aluminum sheets at temperatures of no less than 270ºF and pressure no less than 1000 psi. The aluminum sheets shall not be less than 0.025-inch in thickness when used as a facing on plywood. The aluminum sheets shall not be less than 0.081-inch in thickness when not laminated to a substrate such as plywood.

The bond between the melamine and aluminum sheets shall, as a minimum, meet the following requirements:

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

17.14 Phenolic Composite Floor Panels

Phenolic Composite Panels shall mean panels constructed of top and bottom fiberglass reinforced phenolic resin matrix skins encapsulating a 0.65" thick rigid cell foam or end grain balsa core. The panel skins shall be comprised, at a minimum, of 24 oz/square yard bi-axial and 9 oz/square yard mat laminated on each side of D100 balsa coring. The corresponding minimum skin thicknesses shall be 0.050 inches thick.

- The thickness of the phenolic resin matrix skins shall be increased, if necessary, to meet the strength and requirements of Section 03.
- The panel structure shall contain a dense fiberglass reinforced phenolic resin close-out core to provide support for all edges, cut outs and holes.
- The panel shall be manufactured using the matched die molding process with the application of heat and pressure. Production techniques shall ensure that the glass fiber reinforcement is uniformly distributed throughout the final product in such a manner as to avoid resin-rich or resin-starved sections.
- Fastener holes shall be pre-drilled and countersunk to accommodate the approved fasteners.
- The panel shall meet the following requirements:

Mechanical Properties	**ASTM Test**	**Requirement**
Flatwise Tension	C 297	Strength greater than 1300 psi
Flatwise Compression	C 365	Strength greater than 1210 psi
Flatwise Shear	C 273	Strength greater than 310 psi
Flexural Properties	C 393	For a span of 15 inches, failure load greater than 155 lb/in

17.15 Fiberglass-Reinforced Plastic

Fiberglass-reinforced plastic (FRP) shall be a laminated material, composed of a gel-coated surface and fiberglass reinforcement in an approved thermoset polymer resin matrix. FRP shall be manufactured by an open molding or matched die molding process. Production techniques shall ensure that the glass fiber reinforcement is uniformly distributed throughout the final product in such a manner as to avoid resin-rich or resin-starved sections.

Finished exposed gel-coated surfaces shall have a minimum gloss value of 85 when measured with a 60 degree gloss-meter and shall exhibit no print through of the reinforcements or have any appreciable orange peel. FRP parts shall have a minimum thickness of 0.125 inch and shall have a greater thickness at attachment points and edges, unless otherwise approved.

Fiberglass parts having sanded surfaces, cut edges, or loose fiberglass fibers which are exposed to passengers (e.g., seat back shell) or maintenance personnel shall be sealed with the resin utilized in the construction of the composite or a two-part epoxy paint to completely seal and lock in any exposed fibers.

The resin shall be a commercial grade, thermosetting, polyester, phenolic, vinyl-ester, or acrylic material selected to meet the physical and molding process requirements. The fiberglass reinforcement shall be mat, fabric woven roving, continuous roving, spun roving, or swirl mat as required to meet the physical properties of this Specification and the molding process requirements. The glass content shall be a minimum of 20 percent by weight, and shall be confirmed through testing to ASTM D 2584. The gel coat shall have a minimum thickness of 0.016 inches and a maximum thickness of 0.030 inches. If the surface of the FRP panel is to be painted, a primer gel coat shall be used.

Independent laboratory test certificates shall be provided stating that the production reinforced plastic material complies with the requirements of the following standards. Test specimens shall be conditioned in accordance with ASTM D618.

Minimum Requirements for items which are non-structural or will not be exposed to any loads such as window masks, destination sign shrouds, ceiling cove panels, ceiling headers, etc.

Mechanical Property	ASTM Test	Open Moldings or Matched Die Moldings
Tensile Strength	D 638	10,000 psi
Compressive Strength	D 695	18,000 psi
Flexural Strength	D 790	15,000 psi
Impact Strength	D 256	10 ft-lb per inch of notch
Hardness	D 2583	45 Barcol

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

Mechanical Property	ASTM Test	Open Moldings or Matched Die Moldings
Tensile Strength	D 638	18,000 psi
Compressive Strength	D 695	24,000 psi
Flexural Strength	D 790	30,000 psi
Impact Strength	D 256	13 ft-lb per inch of notch
Hardness	D 2583	45 Barcol

17.16 Thermoplastic Sheet

Thermoplastic sheet used in the construction of this vehicle shall withstand, without any physical deformation or structural damage, the operating environmental conditions and shall be resistant to cleaning solutions. Thermoplastic sheet shall be homogeneous and extruded from virgin stock which does not include any regrind of vacuum formed parts. Only UV stabilized pigments shall be used to create the specified color of the thermoplastic sheet.

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

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

17.17 Seat Upholstery Material

Cloth fabrics used for seat upholstery shall be made of woven, transportation grade fabrics of wool or wool/nylon blend (90/10, 85/15). The maximum fabric shrinkage shall be 2 percent in either the warp or fill direction. Wool/nylon blend seat upholstery material shall be subjected to the physical tests of textile products required by the latest revision of the following ASTM methods, and the results shall not be less than the following values:

Test Number	Description	Criteria
D-3776	Fabric Weight	15.5 oz/sq yd without back coating
D-3775	Fabric Count	Warp – (ends) 88 epi Fill – (picks) 40 to 72 ppi
D-5034	Breaking Strength and Elongation	Warp – 200 lbs Fill – 200 lbs
D-2261	Tear Strength (Tongue)	Warp – 20 lbs Fill – 20 lbs
D-4034	Yarn Slippage	Warp – 30 lbs Fill – 40 lbs
D-3597	Color Fastness	Water – Class 4 minimum Solvent – Class 4 minimum Crocking – Class 4 minimum Light – Class 4 minimum
D-4966	Martindale Abrasion Test	20,000 cycles – no breaks

17.18 Seat Cushion Material

Passenger and cab seat cushion fill material shall be low-smoke flexible foam constructed of inherently fire-retardant materials. The thickness shall be subject to approval during design review. The material shall have a polymerized or vulcanized homogeneous (free from foreign material) cellular structure with a porous surface and open cells.

Non-silicone flexible low smoke foam shall meet the following physical property criteria when tested without upholstery material:

- Tensile Strength – 12.0 lbf/in² minimum when tested to ASTM D 3574 Test E
- Elongation – 150 percent minimum when tested according to ASTM D 3574 Test E
- Compression Set at 50 percent – A maximum of 10 percent when tested according to ASTM D 1055
- Flex Fatigue – Thickness loss 5 percent maximum when tested according to ASTM D 1055
- Tear Strength – 2.0 lbf/in² minimum when tested according to ASTM D 3574

- Silicone foam shall meet the following physical property criteria when tested without upholstery material:
- Tensile Strength – 15 lbs. /in² minimum when tested to ASTM D 3574 Test E
- Elongation – 100 percent minimum when tested according to ASTM D 3574 Test E
- Compression Set at 50 percent – A maximum of 10 percent when tested according to ASTM D 1056
- Flex Fatigue – Thickness loss of 5 percent maximum when tested according to ASTM D 1055
- Tear Strength – 2.0 lbf/in² minimum when tested according to ASTM D 3574

17.19 Piping

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

Following installation, all piping systems shall be cleaned to remove dirt, metal chips, oily contamination, and moisture. After cleaning, all piping systems shall be pressure tested in accordance with the latest edition of the Code for Pressure Piping, ANSI B31.1. All leaks shall be repaired and the system re-cleaned and retested until leak-free.

At all locations where pipe or tubing passes through holes in the floor, bulkheads, structure, or any fixed member, it shall be rigidly clamped to protect against possible damage or noise due to bearing, abrasion, or car dynamics-induced rattling.

17.20 Paint

Painting materials for all surfaces shall provide a high quality finish resistant to corrosion, chipping, fading, and shall retain the gloss level. The coating shall be a two-part, high solids, low VOC, polyurethane paint system. All components of the paint system shall be provided by the same manufacturer. All paint and filler materials which are to be superimposed to form a finish system shall be mutually compatible and shall be warranted for use as a system by the manufacturer of the components. The painted portion of the carbody, or any of its components, shall be in accordance with the specified color scheme. Austenitic stainless steel portions of the carbody shall not be painted, unless otherwise approved by SMART for cosmetic reasons. Where stainless steel is painted, procedures shall be as recommended by the paint manufacturer for the application, and surfaces shall be properly prepared to ensure adhesion.

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

primed, and painted. Concealed surfaces that can rust or oxidize shall be properly cleaned and coated to prevent corrosion.

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

The final painted or powder-coated surface shall be tested on the first component of the production run to the following criteria.

- Hardness: Pencil Hardness tests shall be performed according to ASTM D 3363. The range of acceptance shall be between H and 2H and shall be the average of ten readings taken from typical surface locations. This is a destructive test and will require the tested surfaces to be repaired.
- Adhesion: Adhesion shall be tested per ASTM D 3359 and achieve a minimum 4B rating. This is a destructive test and will require the tested surfaces to be repaired.
- Thickness: The minimum and maximum dry film thickness shall be provided by the paint supplier. Dry film thickness beyond the manufacturer's recommendations will not be accepted. Non-destructive testing shall be performed to verify final dry film thickness.
- Paint Cure: A solvent rub test shall be performed per ASTM D 5402. The test procedure requires no less than fifty double finger rubs with a cloth wetted in acetone or methyl isobutyl ketone to the painted surface. No paint color should transfer to the cloth. After 72 hours, the painted surface must retain all original characteristics such as gloss and hardness.

The following items shall not be painted:

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

The following truck-related items shall not be painted:

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

The supplier shall submit color samples of proposed exterior carbody paints **[CDRL 17-3].**

17.21 Flammability, Smoke Emission, and Toxicity Requirements

17.21.1 General

All combustible materials used in the construction of the cars shall satisfy the flammability, toxicity and smoke emissions requirements of this Section and 49 CFR 238.103 and NFPA 130 and be tested for heating value (Btu/lb and Btu/hour) to ASTM E 1354 at a heat irradiance of 50/Kw/m2. In case of conflict, the more restrictive requirement shall prevail. The Contractor shall comply with all provisions of 49 CFR 238.103 (c), "Fire Safety Analysis for Procuring New Passenger Equipment," and APTA RP-PS-005-00, "Fire Safety Analysis of Existing Passenger Rail Equipment." The Contractor shall prepare and submit a Fire Safety Analysis of the design and materials of construction of the vehicle as part of the design phase of the Contract **[CDRL 17-4].** The analysis shall include a combustible content matrix.

Test reports from an independent laboratory indicating successful testing and demonstrating compliance with these requirements for all materials shall be submitted, along with a test summary table, to SMART for review and approval **[CDRL 17-5]**. Testing shall be conducted after the Contractor's NTP and on a production batch of material intended to be used on the vehicle. For test reports submitted from previously performed tests, the Contractor shall demonstrate that materials included in the test report are identical to the actual materials used in the construction of the vehicles. Test data from these reports shall be dated no more than five years old from the Contract Award Date and shall be identified as a previously performed test in the test summary table. The Contractor shall be responsible for complete conformance with the requirements for itself and its subcontractors and suppliers.

17.21.2 Floor Assembly Fire Resistance Testing Criteria

The Contractor shall test the floor assembly in accordance with ASTM E 119 to demonstrate a 30 minute endurance rating.

17.21.3 Toxicity

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

All materials used in the car construction, except for materials used in small parts such as knobs, rollers, fasteners, clips, grommets, and small electrical parts that would not contribute significantly to fire propagation or to smoke or toxic gas generation and are distributed throughout the car, shall be tested for toxicity using Boeing Specification Support Standard BSS 7239. Materials shall meet the following maximum toxic gas release limits (ppm) as determined per BSS 7239:

- Carbon Monoxide (CO) 3,500 ppm
- Hydrogen Fluoride (HF) 200 ppm
- Nitrogen Dioxide (NO2) 100 ppm
- Hydrogen Chloride (HCL) 500 ppm
- Hydrogen Cyanide (HCN) 150 ppm
- Sulfur Dioxide (SO2) 100 ppm

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

17.21.4 Electrical Fire Safety

Electrical equipment, wiring and apparatus shall conform to NFPA 130, Section 8.

17.22 Wire and Cable

17.22.1 General

Carbody wire shall be as specified in APTA RP-E-009-98 “Recommended Practice for Wire Used on Passenger Equipment” and AAR RP-585. Flame-retardant, flexible, irradiated, cross-linked polyolefin insulation rated at 125 degrees C is approved for general car wiring. All vehicle wire shall be reviewed and approved by SMART **[CDRL 17-6].**

17.22.2 Wire Insulation for High Temperature Applications

The insulation shall have a continuous temperature rating of 150 degrees C or above and be in accordance with the following requirements:

- For wire sizes AWG 16 and larger: abrasion resistant Teflon Polytetrafluorethylene (PTFE) meeting MIL W 22759/6B, or silicone rubber meeting AAR Standard S 503(No.59)
- For wire sizes AWG 18 and smaller: Kapton film insulated/liquid H aromatic polyamide covered per MIL W 81381/22 (AS) or abrasion resistant PTFE Teflon meeting MIL-W 22759/6B. 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.

The Contractor shall submit all applications of high temperature wire insulation for approval.

17.22.3 Wire Insulation in Equipment

Wiring within replacement modular units, electronic apparatus such as cards and card racks, and other equipment, as approved, may be Tefzel Ethylenetetra-fluoroethylene (ETFE) per ASTM D 3159 and insulation construction per Military Specification MIL-W-22759/16 (AS) except the wall thickness shall be 0.6 mm, cross-linked polyolefin or Teflon Polytetrafluorethylene (PTFE) type EE per Military Specification MIL W 16878/5.

17.22.4 Wire Insulation in Crowded Locations

Wire for connections to the control console, or in other locations with similarly crowded low voltage control wiring, may be insulated with ETFE Tefzel per ASTM D 3159 and insulation construction per Military Specification MIL-W-22759/16 (AS) except the wall thickness shall be 0.6 mm.

17.23 Wiring Installation

17.23.1 General

All car wiring shall be in conformance with APTA RP-E-002-98 “Recommended Practice for Wiring of Passenger Equipment”, APTA RP-E-009-98 “Recommended Practice for Wire Used on Passenger Equipment”, and Chapter 3 of the National Fire Protection Association's Publication NFPA No. 70, National Electric Code, except where otherwise specified, and except that all wire shall be as specified in this document.

All car wiring shall have circuit protection conforming to Chapter 2 of NFPA publication No. 70, Article 240 or as specified in this document.

17.23.2 Wiring

Wiring shall be sized for the intended load, voltage drop, installation method, and applicable codes.

Regardless of the load, minimum wire sizes shall be as follows:

- Wire which is pulled through conduit: 14 AWG
- Wire on electronic units, cards, and card racks: 28 AWG
- Wiring which is laid in, rather than pulled through, wire ducts: 16 AWG

Wires sizes other than the above shall be only as approved.

17.23.3 Wire Handling

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

17.23.4 Circuit Separation

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

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

- High voltage circuits
- AC circuits
- Communication circuits
- Battery voltage level circuits
- Semiconductor voltage level circuits

Wiring operating at potentials differing by 50 V or more shall not be harnessed or cabled together or be run in conduit together. Wiring of different voltage potentials in wire ducts, raceways, junction boxes, or other wire routing devices shall be separated by a rigid physical barrier.

Wiring of different potential within equipment enclosures shall be separated, routed, and secured such that contact between wiring is not possible. All wiring within an enclosure shall be insulated for the highest voltage in the enclosure, unless approved otherwise.

Separation and/or electromagnetic shielding shall be provided between the conductors of high current switching or transient generating equipment and the wiring of semiconductor, logic, or communication circuits such that interference does not occur between circuits.

17.23.5 Routing of Wiring

All wiring shall be secured and protected against movement, chafing, and any contact with conductive, sharp, or abrasive objects including the inside surfaces of wire runs.

No wiring shall be secured directly to the car structure, equipment enclosures, or any metallic surface. Wiring securement devices shall be either completely non-metallic or metallic with a resilient, insulating member between the wiring and the metallic portion of the device.

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

17.23.6 Marking

The Contractor shall devise a wire and terminal designation system that will coordinate all electrical circuits in the car into a unified system. The system shall identify all wiring, including circuit return wiring, and all terminals, according to their respective circuit function(s), and shall accurately correlate with the Integrated Schematic Diagrams. Common designations for return circuits are not permitted. Alternative designations may be used with SMART approval in small standard assemblies, such as PA amplifiers.

All wires and terminals shall be clearly identified with white or yellow permanent markers, with black printing or by continuous wire marking printed on the wire. The markers shall be oil and grease resistant and shall withstand all combinations of ambient and equipment temperatures. Printing shall be done by machine with permanent ink that will not rub off. Hand printing is prohibited. Color coded wires are permitted as an alternative in small standard assemblies such as PA amplifiers.

Each wire shall be labeled with both its circuit designation, and, if attached to a terminal, its terminal designation. All wires shall be marked within 75 mm of the end of the wire.

17.23.7 Wire Ties and Clamps

Wire ties, clamps, and anchors shall be nylon formulated for resistance to ozone and ultraviolet light, rated for outdoor service, and shall last the life of the car. Wire ties shall be installed with tools with automatic tensioning devices, as supplied by the wire tie manufacturer. Wire ties shall be installed with sufficient tension to restrain the wiring without indenting the wire insulation.

If used, wire tie anchors shall be riveted or screwed to rigid structure. Adhesive-based wire tie anchors are not permitted.

Wire tie width shall be selected for intended wiring load and minimum insulation indentation.

Wire clamps shall be either nylon or stainless steel covered with neoprene or silicon rubber such as those manufactured by Adel. Wire clamps shall be sized for each harness such that no less than 90 percent of the harness circumference is securely clamped. Clamps shall be fastened with bolts and elastic stop nuts.

17.23.8 Spare Wires

Spare wires, which are part of a wire harness, shall be bundled separately inside of the equipment box to which the harness is being terminated. Spare wires shall have enough length to reach any location within the box, including sufficient slack for the required number of reterminations. The spare wire "break-out" bundle may be ty-wrapped to the main harness, but shall be easily removed from the main harness without disassembling it. The ends of the spare wires shall be insulated against inadvertent contact with any nearby conductive surfaces or terminals.

17.23.9 Nicked or Broken Wires

When removing insulation, wire strands shall not be nicked or broken in excess of the requirements of FAA Specification No. AC 43.13-1A, Section 449, Stripping Insulation. Additionally, the following criteria apply:

Wire Size	**Maximum Number of Nicked Strands**
Wires smaller than No. 10	None
No. 10 through 1/0	7.4 percent
1/0 through 1600/24	4.4 percent
1600/24 through 2750/24	2.0 percent

Definitions:

1. A cutoff strand shall count as two nicked strands.
2. A nick is defined as 25 percent or more of the strand area damaged, or cut more than 33 percent of its diameter.
3. Longitudinal scratches in a copper strand are not considered cause for ejection.

17.24 Wiring Connections

All car wiring shall be connected via terminals and terminal boards and/or multi-pin connectors.

17.24.1 Terminal Boards

As used in this document, the term "terminal board" refers to all devices commonly called terminal blocks, terminal strips, terminal studs, or similar to which wires are connected.

The conducting portion of all terminal blocks shall be plated copper. Clamps, screws, or other hardware may be plated steel.

Terminal boards for power circuits, or for any wire size greater than AWG 8, shall be stud type, with barriers between all terminals.

Terminal boards for control circuits shall be either compression clamp, or push-on tab (FASTON, for example) with barriers between all terminals.

Each terminal board shall have a minimum of 10 percent, but no fewer than one, unused terminals. For terminal boards with more than 100 terminals, the minimum number of unused terminals shall be 10 plus 2 for every 50 additional terminals above 100. Jumpers between adjacent terminals shall be plated brass or copper.

On compression clamp terminal boards, a maximum of 2 terminals shall be connected to any one binding terminal. All connected wires shall be terminated with mechanical crimp type terminals as specified in below.

17.24.2 Wire Terminations

Wire terminals used throughout the car shall be mechanical crimp type terminals as made by AMP Incorporated, or other approved manufacturer with a comprehensive line of terminals, connector pins and application tools available. All terminations shall be plated copper. The Contractor shall submit the proposed product line for approval **[CDRL 17-7].** Spade and hook type terminations are not permitted.

Terminals used on conductor sizes No. 10 AWG or smaller shall be insulated and shall have a metal strain relief device under the insulation that is crimped onto and grips the wire insulation simultaneously with the terminal. Other strain relief devices shall be submitted for approval. The insulation material shall be rated for the expected worst case temperature.

All wire terminals and connections shall be attached to the wiring with crimping tools and dies as recommended by the manufacturer and approved by SMART. Crimping tools shall be ratcheting types that insure a complete compression. The contractor shall maintain these tools in proper calibration and insure that all personnel using them are properly trained.

A maximum of 1 wire shall be crimped in any one terminal.

17.24.3 Power Wiring Terminations

Power wiring shall be terminated with bolted compression terminals as manufactured by AMP, Thomas & Betts, or approved equal and shall be applied using tools and procedures recommended by the terminal manufacturer. Crimping tools shall be ratcheting types that insure a complete compression.

Double bolted terminals shall be used at all locations where rotation of a single bolted terminal would result in contact or unacceptable clearance with other conductors or the enclosure.

Traction motor wire terminals may be as recommended by the motor manufacturer, subject to approval.

17.24.4 Multi-Pin Cable Connectors

All cable connectors shall be equipped with removable crimp contacts. Contacts shall be selected for the intended wire size and as recommended by the manufacturer.

Adjacent connectors shall either use different inserts or different insert orientations to prevent erroneous connections.

Cables shall be clamped at the back of the connector by clamping over the cable jacket. Clamping on cable wires is prohibited.

Extension bodies shall be used where necessary to insure that there is sufficient room to terminate cable wires while providing the seal and clamp on the cable jacket.

17.24.5 Waterproof Cable Connectors

Waterproof cable connectors with the qualities described below shall be used for all under car or exposed locations and may be used at all other locations. Cable connectors shall be equipped with sealing gaskets on the front mating surface and on the back at the cable entry. Unused connector pin positions shall be sealed with either connector contacts or plastic sealing plugs designed for that purpose.

The cable connectors shall be metal shelled, positive locking, quick disconnect, environmental watertight connectors. Connectors shall be rated for a minimum life of 2,000 couplings before failure. Connectors shall give audible, visual and tactile indications of full coupling.

17.24.6 Non-waterproof Cable Connectors

In weatherproof interior locations, the use of non-weatherproof connectors is permitted. Connectors shall be Amp Circular Plastic Connectors, Amp Circular Metal Shell, or approved equal.

17.24.7 Ground Connections

Grounding connections to the car body, truck frame, and other car structures shall be made through tinned or silver electro-plated copper pads silver soldered or brazed to both the carbody and the grounded item.

All grounding wires shall be sized to limit voltage rise to less than 50 V under worst case fault currents. The grounding connection method employed shall not produce a dc resistance in excess of 0.0025 ohms, or more than 0.025 ohms at 150 kilohertz for any applied ac voltage.

Grounding wires to resiliently mounted equipment, from the carbody to truck frame, or other locations with relative movement, shall be tinned braided copper ground cables fitted with flared terminal barrels designed for strain relief.

Grounding wires to fixed equipment may be standard car wiring.

All ground connections shall utilize bolted terminals. All ground pads shall be through-drilled and the ground wire fastened with a bolt, flat washer and locknut. The flat washer shall bear on the ground wire terminal.

17.24.8 Wire Splicing

Wire splicing is not permitted.

17.25 Electrical and Electronic Designs

Refer to Section 11 Electronic Control, Software and MDS System for material and design requirements.

17.26 Electrical Devices and Hardware

All electrical devices shall be rail industry proven.

17.26.1 Contactors and Relays

All contactors and relays shall have a documented successful history of operation in rail transit control applications.

The coils of all devices shall be suppressed except where performance may be affected. Unsuppressed coils are permitted only with the explicit approval of SMART.

Contact current ratings shall be based on continuous, inrush, or interrupting requirements, whichever is worse, and then derated by at least a factor of four. Contact materials shall be selected for the actual loads, and not solely on the device rating. Silver bifurcated contacts and gold alloy bifurcated cross bar contacts shall be used on low level and dry circuits, respectively.

Contacts connected in series shall not be operated in circuits where the voltages and currents exceed the single derated contact ratings. Contacts shall not be connected in parallel.

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

All contactors shall be built with series fed arc blowout coils able to direct an arc over the full range of interrupt capability.

All time delay relays shall be of the R-C or solid state type. Mechanical or pneumatic time delay devices are not permitted.

All relays and contactors shall be identified with the appropriate circuit designation. The label shall not be obscured by wiring or other equipment and shall not be mounted on relay covers, arc chutes, or other removable items.

Plug-in relays shall be provided with a retainer that is captive to the relay socket. The retainer shall be arranged such that, when released, contact cannot be made with energized adjacent circuitry.

All contactors shall have a guaranteed mechanical service life of at least 5 million switching operations, except as approved where infrequent operation is expected.

All relays shall have a guaranteed mechanical service life of at least 10 million switching operations. Contact electrical life shall be no less that 500,000 operations, or 10 years, whichever is greater.

There shall be a maximum of two wire terminations on any relay or contactor terminal.

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

All relays and contactors shall be mounted and oriented as recommended by the supplier.

17.26.2 Switches

All switches shall be oil-tight, industrial grade switches suitable for NEMA type 4 and type 13 applications for exterior and interior uses respectively.

Contacts shall not be operated at voltages or currents in excess of the manufacturer's recommendations. Contact current ratings shall be de-rated by at least a factor of four for all applications. Contacts connected in series shall not be operated in circuits where the voltages and currents exceed the single contact ratings. Contacts shall not be connected in parallel.

Switches shall not directly control highly inductive or high inrush loads. Switch contacts shall be silver, double break. All switch mechanisms shall provide a wiping motion when contacts make or break.

All safety-critical switches, such as those that can cause door openings, shall be designed to withstand a high potential test of 1,500 Volts for one second, in a clean dry condition, without false conduction.

All switch bodies shall be keyed to prevent rotation. All mounting hardware, including the body portion extending through the panel, shall be metal.

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

17.26.3 Circuit Breakers

All circuit breakers shall be rugged and fully suitable for the service intended and of the highest quality procurable. Design and selection of all circuit breakers shall be subject to review and approval **[CDRL 17-8].**

A separate circuit breaker shall be provided for each branch circuit as well as for each major assembly and each function.

Circuit breaker terminals shall not be used as junction points.

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

17.26.4 Fuses

Fuses are not permitted except where specified or approved.

17.26.5 Switch, Circuit Breaker, and Fuse Panels

Each switch, breaker, fuse, and indicating light shall be provided with a nameplate of raised or recessed lettering on the dead front, clearly identifying the circuit to which each applies, its circuit designation, operating voltage and instructions such as “Do Not Operate Under Load” as appropriate. The dead front panel shall conform to NFPA 70, Article 384. The dead fronts shall be made of moisture-proof, electrically insulating, laminated phenolic. Asbestos shall not be used.

Power distribution to circuit breakers and switches shall be from a bus bar or bus circuit. Distributing power by successive or daisy-chained connections between device terminals is not permitted.

17.27 CDRL

The following submittals are required:

17-1 Material safety data sheets

17-2 List of recommended cleaning agents

17-3 Paint samples

17-4 Fire safety analysis

17-5 Fire, smoke and toxicity test reports and summary table

17-6 Vehicle Wire

17-7 Wire Termination Product Line

17-8 Circuit Breakers

18 TESTING

18.1 General

The Contractor shall perform a comprehensive testing program to demonstrate that the cars meet applicable requirements, standards, and codes, consistent with the requirements of these design criteria.

At its discretion, the Contractor may consider the application of previous test reports and/or service history record in lieu of new testing, but only where it can be demonstrated to the Engineer that the equipment testing and the service application were the same as for SMART.

All appropriate testing documentation shall be prepared in accordance with 49 CFR 238.111 and submitted to SMART for approval no later than 90 days in advance of the start of the test program.

18.2 Test Matrix

During the design phase, the Contractor shall develop a test matrix listing tests to be performed during the test program. This test matrix shall be approved by the SMART before test scheduling may begin. The test matrix shall be updated regularly to accurately capture any changes to program scope or direction. **[CDRL 18-001]**

18.3 Test Schedules

Test schedules shall be prepared during the design phase for all tests listed in the test matrix. Test schedules shall be submitted for review and approval by the SMART. The schedules shall be updated regularly (at least monthly) once testing has commenced. The schedules shall identify the type of testing to be performed, the location and date of the testing, the status of the applicable test specification, and the representation required at the test (e.g. vendor, Contractor, SMART, etc). **[CDRL 18-002]**

18.4 Test Procedures

The Contractor shall prepare a test procedure in advance of each test for review and approval by the Engineer. No test shall be performed by the Contractor or any Subcontractor without a test procedure that has been approved by the SMART. **[CDRL 18-003]** The Contractor shall submit one test procedure for each unique test, recorded as a unique Contract Deliverable. The Contractor shall develop a numbering scheme (ie. CDRL 18-003A, 18-003B, …) to accurately track test procedure submissions and allow one test to be closed out without unnecessary dependence on other tests.

18.5 Test Reports

For each test performed, a test report shall be prepared, regardless of the outcome of the test, and submitted to the Engineer. **[CDRL 18-004]** The Contractor shall submit one test report for each unique test, recorded as a unique

Contract Deliverable. The Contractor shall develop a numbering scheme (ie. CDRL 18-004A, 18-004B, …) to accurately track test report submissions and allow one test to be closed out without unnecessary dependence on other tests. A register of all test reports shall be submitted on a monthly basis. **[CDRL 18-005]**

18.6 Required Testing

The following test titles shall be incorporated into the Contractor's test program. The Contractor shall define the scope and magnitude of these tests in order to fully demonstrate compliance with the requirements of these design criteria.

18.6.1 Component and System Type Testing

1. Carbody Interior Materials Tests
2. Window Tests (including Emergency Windows)
3. Flammability, Smoke and Toxicity Emission Tests
4. Door Panel
5. Door System Endurance Test
6. Heating, Ventilation and Air Conditioning
7. Coupler, Drawbar, and Draft Gear Tests
8. Auxiliary Power, LVPS, Battery and Battery Charger
9. Truck Frame Static Load Test
10. Truck Frame Fatigue Test
11. Truck Frame Weld Inspection
12. Truck Primary Suspension Tests
13. Carbody Static Structural Tests
14. Operational Safety Testing (ATC/CSS/PTC, Alerter, Event Recorder)
15. Seat Frame and Cushions

18.6.2 Car Level Type Testing

1. Clearance Tests
2. Roll Angle Tests
3. Trainline Tests
4. Door Operation Tests
5. Heating, Ventilation and Air Conditioning
    a. Fresh Air Duct Watertightness Tests
    b. System Air Flow Tests
    c. Climate Room Tests
6. Lighting Tests

7. Brake Shoe and Disc Pad Force Tests
8. Parking Brake Tests
9. Truck Equalization and Stability Tests
10. Electromagnetic Emissions Tests and Limits
11. Communications System Tests
12. Closed Circuit Television (CCTV)
13. Destination Sign and Interior Message Display Tests
14. Auxiliary Power System/LVPS/BCS
15. Primary Power System
16. Operational Safety Systems Test

18.6.3 Road Type Test

1. Noise and Vibration Tests
2. Performance Tests
3. Acceleration Tests
4. Friction Brake Deceleration Tests
5. Dynamic Brake Deceleration Tests
6. Blended Brake Tests
7. Wheel Slip Tests
8. Route Performance
9. Ride Quality Tests
10. Electrical Interference Tests (EMI)
11. Communication System Tests
12. Operational Safety Systems Test

18.6.4 Pre- Delivery (Car Routine) Tests

1. Watertightness Tests
2. Weight
3. Piping Tests
4. Car Wiring Tests
5. Wiring Continuity Test
6. Insulation Resistance Tests
7. High Potential Tests
8. Grounding
9. Trainline Tests
10. Low Voltage DC Supply Tests

11. Primary Power System
12. Door Tests
13. HVAC Tests
14. Headlight, Marker Light, and Auxiliary Light Tests
15. Communication Systems Tests
16. Pneumatic System and Friction Brake/Parking Brake Tests
17. Leveling Tests
18. Lubrication Checks
19. Safety Devices
20. Propulsion Control Systems
21. Operation Safety Testing (ATC/CSS/PTC, Alerter, Event Recorder)
22. Load Weigh System
23. Monitoring and Diagnostics Systems

18.6.5 Acceptance for Revenue Service Tests

1. Car Performance Test
2. Operational Tests

18.7 CDRL

The following submittals are required:

18-1	Test Matrix
18-2	Test Schedules
18-3	Test Procedures
18-4	Test Reports
18-5	Registry of Test Reports

19 SYSTEM SUPPORT

19.1 Manuals

19.1.1 General

Unless otherwise specified, the Contractor shall follow the process for developing and organizing technical documentation as specified in APTA RP I&M-002, latest version, Recommended Practice for Passenger Rail Equipment Technical Documentation. The following technical documents shall be produced for the equipment supplied under this Contract:

- Operating Manual
- Fault Isolation Guide
- Integrated Schematics Manual
- Maintenance Procedures Manual
- Illustrated Parts Catalog
- Education Program

The goals of the technical documents shall be completeness and accuracy of technical material coverage in the most concise manner possible. Abbreviations, acronyms, definitions, and symbols used in the Technical Documents shall comply with the current version of the following standards:

- ASME STD Y14.38, Abbreviations and Acronyms
- IEEE STD 315, Graphic Symbols for Electrical and Electronic Diagrams
- IEEE STD 91, Graphic Symbols for Logic Diagram
- ASME STD Y32.10, Graphic Symbols for Fluid Power Diagrams
- ASTM/IEEE SI10, American National Standard for Use of the International System of Units (SI): The Modern Metric System
- IEEE STD 100, The Authoritative Dictionary of IEEE Standard Terms

19.2 Education Program

The Education Program material shall include a general program outline, and Instructor Manuals containing details of the material to be presented, participant manuals, all supplemental training material, and training aids.

Objectives of the Education Program shall be to train SMART personnel to:

- Become proficient in the operation, inspection, maintenance, servicing, troubleshooting, and repair of the cars.
- Understand and effectively use the Technical Documents provided under the Contract; and
- Select, order, and stock replacement parts for equipment supplied under the Contract.

The Car Builder shall develop a detailed, comprehensive Education Program for all SMART personnel. The Education Program shall be organized into course categories (or modules):

- Introduction and Familiarization - to cover the basic operation and configuration of the cars.
- Operation and Fault Isolation - to cover features and operation of the cars, along with diagnostic strategy for fault isolation.
- Servicing and Maintenance; - to cover detailed maintenance and fault isolation of equipment and systems on the cars.
- Use of the Illustrated Parts Catalog

Training shall incorporate all pertinent information approved by the Engineer and necessary to comply with the requirements of 49 CFR 238.109, including daily and periodic inspections. An initial outline and final draft of the QMP and QP training programs shall be submitted to SMART for review and approval **[CDRLs 19-1 and 19-2].**

The Education Program shall include both classroom and field instruction and be organized into modules to target different personnel and departments.

Nomenclature for all components used in the Education Program shall be in accordance with the terminology used on drawings, schematics and wiring diagrams, and incorporated in operating and maintenance manuals.

The Education Program shall cover SMART staff with the following functional responsibilities:

- Locomotive Engineers and Train Crew
- Maintenance Personnel
    - Field (daily inspections and running repairs)
    - Electrical, TBD students
    - Non-Electrical, TBD students
    - Shop (periodic inspection and heavy repair)
- Procurement (Illustrated Parts Catalogs only)

19.3 CDRL

19-1 QMP and QP Training Program Plan Initial Outline

19-1 QMP and QP Training Program Plan Final Draft

20 QUALITY ASSURANCE REQUIREMENTS

20.1 Quality Assurance Requirements

20.1.1 General

The Contractor shall establish and maintain a Quality Assurance (QA) Program that complies with ANSI/ISO/ASQ Q9001-2000 or approved equal and the FTA QA/QC Guidelines document FTA-IT-90-5001-02. Subcontractors, manufacturers, and suppliers selected by the Contractor, whether foreign or domestic, shall also comply with this requirement.

The QA Program shall assure that all aspects of the Contract are in conformance with the design, materials and workmanship requirements provided in this specification.

The Contractor and its subcontractors shall perform wheel and axle work for this Contract in shops having certification according to the American Association of Railroads Standard AAR M-1003.

The approved QA Programs of the Contractor, subcontractors, manufacturers, or suppliers shall not be changed without SMART's concurrence.

SMART may verify implementation of any aspect of the Contractor's operation as it relates to Quality Assurance or the QA Program at any time.

The Contractor shall perform all work required by its Quality Assurance program and conduct regular quality program audits. SMART may conduct an initial audit of the Contractor's QA Program prior to issuance of the Purchase Order for this Contract.

SMART may suspend the work if the Contractor fails to promptly correct deficiencies identified by SMART via corrective action requests, failure analysis reports, non-conformance reports, or other contractual communication.

20.2 Quality Assurance Plan

The Contractor shall submit a Project Quality Assurance Plan (PQAP) **[CDRL 20-1]** conforming to the requirements of ANSI/ISO/ASQ Q9001-2000 and FTA-IT-90-5001-02 for review and approval no later than 90 days after NTP. This plan shall identify the controls, resources, and skills the Contractor will apply for the duration of the Contract to satisfy project quality system requirements. The PQAP shall address each of the clauses in ANSI/ISO/ASQ Q9001-2000 and FTA-IT-90-5001-02 and provide the following:

- Control of Quality Records
- Document and Data Control
- Management Responsibility for QA Program
- Quality Assurance and Training

- Contract Review
- Manufacturing Plan **[CDRL 20-2]**. Customer-witnessed and hold-point verification lists shall be submitted to SMART for approval.
- Modification Plan **[CDRL 20-3]**
- Test and Inspection Plan (TIP) **[CDRL 20-4]**. Test and inspection procedures shall be subject to SMART review and approval.
- Design Control Plan **[CDRL 20-5]**
- Control of Purchased Items and Services
- Product Identification and Traceability
- Control of Inspection, Measuring, and Test Equipment
- Handling, Storage, Preservation and Delivery
- Warranty Plan **[CDRL 20-6]**
- Control of SMART-Supplied Products
- Internal Quality Auditing
- Controlling Nonconforming Products and Services

20.3 Software Quality Assurance

20.3.1 Software Development Capability Appraisal

The Contractor, as systems and software integrator, and Suppliers, who are providing processor-based products, shall have a mature software and systems development process. To confirm its capability, the Contractor shall contract with an independent third party for an independent SCAMPI Class A appraisal for the Contractor and for each supplier. The appraisal shall use the Capability Maturity Model Integration for Development (CMMI-Development v1.2 or later) as defined by the Software Engineering Institute (SEI) and shall follow the SEI requirements for a Class A appraisal. The resulting Appraisal Disclosure Statement (ADS) and the appraisal findings document shall be submitted to SMART following validation by the SEI.

Since the system engineering, software design, integration, and subcontract management are critical to the success of the project, the Contractor's appraisal is required regardless of whether or not they directly produce software or design systems. In each case, the appraisal must cover the entire range of activities performed by the Contractor or supplier with regard to the project. The specific details of how the appraisals will be conducted and any tailoring issues shall be presented to SMART for approval before the appraisals are performed.

The independent appraisals shall include the use of a Lead Appraiser who is authorized by the Software Engineering Institute (SEI), and shall be conducted according to the methodologies established by the SEI. The Lead Appraiser shall not be affiliated with the Contractor or the suppliers and shall not have been involved with their improvement activities. The Contractor's validated Appraisal Disclosure Statement (ADS) and the appraisal findings document shall be submitted to SMART for approval prior to the first Preliminary Design Review (PDR), and each supplier's results must be submitted prior to the PDR for the relevant subsystem.

If the Contractor's CMMI maturity level rating is below 2, and for each supplier with a CMMI maturity level rating below 2, a course of action must be defined to mitigate the impact of the problem areas on the project and to improve the processes to at least a CMMI level 2 by the time of Final Design Review (FDR).

The Suppliers shall submit monthly progress reports identifying progress-to-plan for improving to CMMI level 2. The reports must demonstrate a concerted effort and tangible results. Reports shall continue up through the submittal of the validated Appraisal Disclosure Statement (ADS) and the appraisal findings for a subsequent CMMI Class A appraisal confirming a maturity level 2 rating.

20.3.2 Software Quality Assurance Plan (SQAP)

The Contractor shall establish and maintain a plan for software quality assurance. The Software Quality Assurance Plan (SQAP) **[CDRL 20-7]** shall comply with the requirements of IEEE STD 730. The Contractor shall submit the SQAP for review and approval 90 days after NTP.

Refer to Section 11 for software development documentation requirements.

The suppliers' software development processes, including proprietary and internal procedures, shall be available for inspection and/or review by SMART during any regularly-scheduled site visit, such as QA audits, Design Reviews, FAIs, or routine hardware inspections. The implementation of any aspect of the Contractor's operation as it relates to the SQAP shall be subject to verification by SMART at any time.

20.4 Design Review Program

The Contractor shall schedule and conduct design reviews for vehicle systems and for systems integration. Equipment and systems subject to design reviews shall be identified in the PQAP. SMART shall participate in all design reviews.

The Contractor shall successfully complete the design review program before requesting SMART to participate in First Article Inspections.

The Contractor shall provide Design Review document packages to SMART at least 15 days prior to the design review.

The Contractor shall structure the design review program to include the following:

- Preliminary Design Review (PDR) **[CDRL 20-8]** to review the system design, including hardware and software. Date(s) for the PDR shall be provided in the Project Schedule.
- Final Design Review (FDR) **[CDRL 20-9]** to review the detail design of the hardware and software furnished to meet requirements of the contract. The review shall include hardware, software, and installation. Date(s) for the FDR shall be provided in the Project Schedule.

Design reviews shall address hardware, software, system integration of interfaces with other systems, performance requirements, special tools and test equipment, technical documentation; and reliability, availability, maintainability, and safety (RAMS).

At the completion of the series of PDRs, and again on the completion of the series of FDRs, the Contractor shall convene a vehicle integration review meeting with system and subsystem suppliers, and SMART. The Contractor and SMART shall mutually agree on the system and subsystem supplier participants for the integration review meetings.

During processes of design development, manufacturing, and testing, the Contractor shall validate the design, confirming that it meets defined SMART requirements.

20.5 Quality Assurance Provisions for Work In-Progress

20.5.1 Corrective and Preventive Action

The difference between corrective and preventive action procedures shall be clearly expressed in the Contractor's PQAP. Corrective action procedures shall address actual nonconformities that have occurred. Preventive action procedures shall address the potential for nonconformity.

The Contractor shall establish and maintain procedures for taking corrective and preventive actions that address the entire scope of the problems encountered and take their risks into account.

For failure of any kind in systems, devices, apparatus, components and parts, the Contractor or its subcontractor, supplier, or manufacturer shall perform a documented failure analysis to determine the root cause of the failure and corrective action(s) to eliminate the problem and cause of failure.

Corrective action procedures shall be effective in handling complaints from nonconformance reports and as reported from each source, including SMART. Methods shall include root cause investigation, problem analysis, recording results, determining the most effective corrective action, verifying that corrective actions have been taken, and that they are effective.

Preventive action procedures shall require use of all available information to eliminate potential sources of nonconformity. Methods shall include data and information analysis, determining the best approaches to preventing nonconformity, implementing and ensuring effectiveness of preventive action plans, and forwarding significant details of actions taken for review by the Contractor's management.

20.5.2 Use of Statistical Techniques

The Contractor's PQAP shall identify specific needs and requirements for statistical techniques in controlling production processes. Statistical quality control application software program(s) used in acceptance of parts, materials, or processes by the Contractor or its suppliers shall be documented and based on recognized and accepted statistical quality control methods. Statistical quality control application software program(s) intended for use on the project shall be defined and submitted to SMART for approval along with the PQAP.

20.6 First Article Inspection (FAI)

20.6.1 General

The Contractor shall submit a FAI Plan **[CDRL 20-10]** that includes a list and schedule of FAIs to SMART for review and approval not later than 120 days after Notice to Proceed.

Before the performance of any FAI, the Contractor shall prepare and submit an FAI Log **[CDRL 20-11]** detailing relevant information for FAIs included in the plan. The log shall include FAI status, pre-FAI submittals, corresponding letter numbers (both submittals and responses), and FAI report status. The Contractor shall keep the log current and submit it to SMART at least once per month until the FAIs are completed.

Equipment shall be shipped from the point of manufacture only after an FAI has been offered, performed, passed and approved by SMART.

SMART reserves the right to participate or waive its participation in any FAI.

The Contractor shall perform independent pre-FAIs to ensure readiness for formal FAIs.

The Contractor shall perform FAIs on components built using approved production processes and tooling, and jointly with SMART shall establish the level of quality of workmanship for the balance of like components.

First Article Inspection will not be conducted until the design drawings of the article have been approved and all open issues from design reviews are resolved. Conditionally Approved drawing status may be considered acceptable for conducting the FAI provided that the Contractor assures SMART that the

drawing review comments will be resolved as agreed with SMART and solutions included in the FAI item and verified by the Contractor during its pre-FAI.

The Contractor shall not conduct the FAI until SMART has approved the FAI package. Conditional Approval status will be considered with the same stipulations as applied to Conditionally Approved drawings as mentioned above.

In the event the Contractor schedules Type tests immediately following an FAI or in conjunction with the FAI, the Type test procedures must be submitted to SMART for review and approval prior to testing. Prior to conducting any Type test, the Contractor shall conduct a FAI of each component.

The Contractor shall provide an individual notice to SMART for each FAI at least 30 calendar days prior to the FAI. The Contractor shall not schedule more than two FAIs on the same date or two FAIs in different locations within the same work week without prior approval by SMART.

20.6.2 FAI Components, Equipment, and Apparatus

The Contractor shall perform FAIs for all components, equipment, and apparatus at the source of manufacture or assembly.

Inspected “First Articles” (components, equipment, and apparatus) shall be retained for the duration of the manufacturing period and stored in a secure area at the Contractor's facilities. These items shall be made available for inspection and comparison at the request SMART. These items may be utilized for production of the last cars with prior approval by SMART, and provided these items conform to the latest, current, approved configuration.

In addition to the at-source components, equipment, and apparatus, FAIs shall be conducted for the following:

- Complete car underframe structure
- Side frame structure
- Roof structure
- End structure
- Floor structure
- Complete assembled carbody structure
- Complete underfloor equipment installation
- Complete assembled and integrated cabs
- Complete assembled truck
- Exterior paint, decal, and finish scheme
- Each Pilot Car type with vehicle systems fully assembled, integrated into the car, and fully operational.

20.6.3 FAI Package Requirements

At least 30 days before conducting each FAI, the Contractor shall submit to SMART a FAI package for review and approval. Each package shall be identified as a CDRL, with a unique number suffix **[CDRL 20-12-xxx]** identified in the FAI Plan. The Contractor shall submit a FAI package to SMART in advance of the FAI to provide the following:

- Schedule and agenda of inspection
- Vendor name
- Vendor address
- Vendor phone number
- Vendor contact
- Component list with latest drawing status for the equipment to be inspected
- Contractor inspection plan.
- Participating Contractor representatives
- A complete set of approved or conditionally approved drawings and software documentation (with SMART comments) for the item to be inspected.
- For purchased items, a copy of the vendor's purchase order with commercial items excluded.
- Completed vendor inspection forms that control and document acceptance of in-process work.
- Completed vendor and Contractor final inspection reports and applicable certification(s).
- Completed test documents that reflect that the unit has passed the Type Test(s).
- Inspection work space that provides the proper environment for inspection of the piece part, subassembly, or car.
- Inspection tooling and test and measurement equipment
- Performance of routine test to the approved test procedure.

20.7 Serial Numbers

The Contractor shall furnish SMART with a record of the serial numbers for major components as approved by SMART on all cars as delivered. Car History Books shall also include serial numbers. The Contractor shall submit:

- Serial Number List by system and components, of the serial numbers for each system and component **[CDRL 20-13]**.
- Serial Number List by car number, of the serial numbers of systems and components on each car **[CDRL 20-14]**.

20.8 Configuration Management

20.8.1 General

The Contractor shall maintain accurate and current configuration control records, which shall be available to the SMART throughout the period of performance of the Contract and for a three-year period after final Contract payment.

The Contractor shall ensure that its subcontractor, supplier, or manufacturers' equipment, as incorporated into the vehicle design, complies with the requirements specified in this Section.

The Contractor shall prepare and submit a Configuration Management Plan **[CDRL 20-15]** within 90 days after NTP to SMART for review and approval. This plan shall detail how the Contractor intends to meet the configuration management requirements.

The Contractor shall prepare technical documentation to acceptable commercial standards and shall be capable of defining the approved configuration of system equipment in development, test, production, or operational use.

The technical documentation shall identify the configuration to the lowest level required to ensure repeatable performance, quality, and reliability.

The Contractor shall employ and maintain release records for technical documentation which shall portray the relationship between identification elements. Such relationships shall be limited to configuration requirements defined by engineering data. It shall not reflect hardware or other product condition that varies from engineering requirements contained in these data, and shall not reflect manufacturing status.

20.8.2 Software Configuration Management

Software configuration management shall be described in a separate Software Configuration Management Plan (SCMP) **[CDRL 20-16]**. The SCMP shall include policies and procedures for ensuring software revision control for the software work products throughout the Contract life cycle. The SCMP shall comply with IEEE STD 828 and IEEE STD 1558.

20.9 Reference Standards

AAR – M-1003 – Manual of Standards and Recommended Practices, Section J, "Specification for Quality Assurance"

ANSI/ISO/ASQ Q9001-2000 – "Quality Management Systems – Requirements"

IEEE STD 730 – "Standard for Software Quality Assurance Plans"

IEEE STD 828 – "Standard for Software Configuration Management Plans"

IEEE STD 1012 – “Standard for Software Verification and Validation”

IEEE STD 1558 – “Standard for Software Documentation for Rail Equipment and Systems”

FTA-IT-90-5001-02 – “Quality Assurance and Quality Control Guidelines”

20.10 CONTRACT DELIVERABLE REQUIREMENTS

Contract Deliverable Requirements	
20-1	Project Quality Assurance Plan (PQAP)
20-2	Manufacturing Plan
20-3	Modification Plan
20-4	Test and Inspection Plan (TIP)
20-5	Design Control Plan
20-6	Warranty Plan
20-7	Software Quality Assurance Plan (SQAP)
20-8	Preliminary Design Review (PDR)
20-9	Final Design Review (FDR)
20-10	FAI Plan
20-11	FAI Log
20-12-xxx	FAI Package
20-13	Serial Number List, by system and components
20-14	Serial Number List by car number
20-15	Configuration Management Plan
20-16	Software Configuration Management Plan (SCMP)

Acronyms: (to be moved to the overall Acronym list in the final revision of the specification)

Acronyms	
FAI	First Article Inspection
FDR	Final Design Review
PDR	Preliminary Design Review
PQAP	Project Quality Assurance Plan
QA	Quality Assurance
QC	Quality Control
RAMS	Reliability, Availability, Maintainability, and Safety
SCMP	Software Configuration Management Plan
SQAP	Software Quality Assurance Plan
TIP	Test and Inspection Plan