SECTION 1

GENERAL TOPICS AND DEFINITIONS

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SECTION 1

GENERAL TOPICS AND DEFINITIONS

1.1 Introduction

The Contractor shall design, manufacture, test and deliver the products as described by this specification. Deviations from these requirements are permitted only with specific approval of SDOT.

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 insure that all designers, suppliers, and subcontractors are informed of all specified requirements and that appropriate engineering management tools are utilized to insure 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 conform to 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 SDOT on a case-by-case basis, and all restorations shall be performed by the original equipment manufacturer.

1.2 Specification Organization

This Specification is divided into sections according to technical discipline and traditional supplier arrangements. This format is for convenience only and does not imply or suggest a preferred system integration approach.

Explicit references may appear within sections linking requirements appearing in other sections. Such references shall, in no way, be assumed to limit the range or applicability of any requirements in this document, whether referenced or not.

1.2.1 Contract Deliverables

This specification requires the submittal of drawings, documents, analyses, test results, manuals and similar information for review by SDOT to verify compliance with specified requirements, and for after-delivery support of the vehicles. Specific submittal requirements are listed at the conclusion of each section under the heading contract deliverables requirements list or CDRL. Typically, the CDRL submittals in each section relate to the design requirements in that section. Those design drawings requiring submittal and approval are identified in Sections 2 through 14. Final drawings requiring submittal are discussed in Section 19. Other documents requiring submittal and approval are identified in the CDRL requirements in Sections 2 through 19.

Regardless, if noted as submittals in the text, the Contractor is obligated to forward them for review and approval even though they may not appear in the CDRL section.

1.3 Definitions

The following terms may appear in this document. They are defined as indicated:

Adhesion, Coefficient of: During rolling contact, the ratio between the tangential force at the wheel-rail interface and the normal force.

Approval: Acceptance in writing by SDOT or SDOT's Engineer.

Approved or Approved Type: Design, type material, procedure, or method given approval by SDOT or SDOT's Engineer.

AW0: Weight of empty vehicle.

AW1: Weight of vehicle with full seated load.

AW2: Weight of vehicle with a full seated load plus standees at 4 passengers/m^2.

AW3: Weight of vehicle with a full seated load plus standees at 6 passengers/m^2.

AW4: Weight of vehicle with a full seated load plus standees at 8 passengers/$m^{2.}$

Blending: In braking, the simultaneous control of dynamic (rheostatic and regenerative) and friction braking, with the effort of each continuously proportioned to achieve the required total braking effort within the specified tolerances.

City, the: the City of Seattle

Coast: The mode of operation in which no propulsion (positive traction) or braking effort is in effect, except for normal drivetrain losses.

Contract Drawings: Drawings provided by SDOT as part of this procurement.

Contractor: The person or persons, firm, partnership, corporation, or combination thereof which has entered into a procurement contract with SDOT to supply the vehicles.

Contractor's Drawings: Items such as general drawings, detail drawings, graphs, diagrams, sketches, calculations, and catalog cuts prepared by the Contractor for use in its manufacturing facility, assembly facility, or shop, to fabricate, assemble, and install parts of the vehicle whether manufactured by it from raw materials or purchased from others in a ready-to-use condition.

Days: Unless otherwise designated, days as used in the Contract Document will be understood to mean calendar days; that is, including weekends and holidays.

Days, Working: Those calendar days during which regular business is conducted excluding Saturdays and Sundays and all Federal, State, and municipal holidays that are observed in Seattle, Washington.

Drive: A system consisting of one or several motors or actuators, their direct control equipment (power circuits), and the associated mechanical devices required to produce a useful output.

Equal: Providing the same function, performance, and reliability.

Failsafe: A system is "failsafe" when it is designed such that any malfunction will not cause the system to achieve an unsafe state.

Failure: A condition in which equipment does not function as specified, designed, or expected.

Failure Rate: The frequency of failure, expressed as failures per hour or failures per mile. Failure rate is the mathematical reciprocal of MTBF or MDBF.

First Article: The first item of production that fixes and defines all subsequent production items. First articles are production units intended for review by SDOT.

Inspector: The person(s) or firm designated by SDOT as its quality control representative.

Interface: The points where two or more systems, subsystems, or structures meet, and transfer energy and/or information.

Jerk: Time rate of change of acceleration and deceleration, equal to the second derivative of velocity.

Light: The transparent portion of a window.

Liner (as in interior liner): The visible covering material for the walls, ceiling, and other interior surfaces.

Load Weighing: The measurement of passenger load for the purpose of adjusting tractive effort to produce a constant acceleration or braking rate regardless of load.

Mask, Window: Interior liner that surrounds the windows, often molded to include the sill and other portions of the sash.

Mean Distance Between Failures (MDBF): The mean operating mileage between independent failures.

Mean Time Between Failures (MTBF): The mean operating time between independent failures.

No Motion Speed: The lowest speed detectable by the vehicle control systems.

Normal: As in, example, "normal operating conditions" or "operating normally". A condition in which relevant vehicle equipment is not in a failure mode and the environment is functioning as specified.

Proof (used as a suffix): As in splashproof, dustproof. The device and contents are impervious to, or unharmed by, application of the indicated action or material.

Reliability: The probability of performing a specified function, without failure and within design parameters, for the period of time indicated.

Safe: Secure from liability to harm, injury, danger, or risk; free from danger or risk.

Safety: The condition in which persons are free from threat or danger, harm, or loss arising from improper design, manufacture, assembly, malfunction, or failure of the car or any of its components or systems.

Service, as in Service Use, Service Braking: The operation of the cars under normal conditions.

Slide, Wheel: During braking, the condition existing when the rotational speed of the wheel is less than that for pure rolling contact between tread and rail.

Speed, Balancing: The speed attained by the vehicle or train when resisting forces exactly equal the maximum available tractive forces.

Speed, Base: The speed to which the maximum constant acceleration can be maintained at the nominal line voltage.

Speed, Schedule: The average speed of a vehicle or train, from terminal-to-terminal, obtained by dividing the distance between these points by the time taken to make the trip, including time for intermediate station stops.

Spin, Wheel: During acceleration, the condition existing when the rotational speed of the wheel is greater than that for pure rolling contact between tread and rail.

Stop, Emergency: The stopping of a vehicle or train by an emergency brake application.

Stop, Service: The stopping of a vehicle or train by application of service braking.

Tight (used as a suffix): As in watertight, airtight, enclosed or protected as to completely exclude the indicated material from passage.

Time, Build-Up: In response to a step-forcing function, time interval from 10% of the total change in value to the attainment of 90% of the total change in value of the controlled variable. Build-up time is equal to response time minus dead time.

Time Constant: Slope of controlled variable build-up curve in units of controlled variable per unit of time, measured during the build-up time interval.

Time, Dead (also Time, Reaction): Time from the occurrence of a step change of the control signal to the attainment of 10% of the total change in value of the controlled variable.

Time, Response: Time from the occurrence of a step change of control signal to the attainment of 90% of the total change in value of the controlled variable.

Time, Warm-up: The elapsed time from the application of power to an operable device until it is capable of performing its intended function.

Tram: "In tram" is the condition of ideal truck geometry in which the axles are perfectly parallel and the wheels are in perfect longitudinal alignment. The centers of the journal bearings represent the corners of a perfect rectangle. Verification that a truck is "in tram" is determined by measuring the diagonal and longitudinal distance between reference points on the axle bearing housings.

Vehicle: A complete streetcar assembly as described by this specification, ready to operate.

Vital: A term applied to a device or circuit which has known failure modes, certain of which occur with extreme rarity

Wainscot: The lower portion of a wall, especially if finished differently from the upper portion.

Warp, Track: The vertical distance between the plane of any three of four rail head contact points (two on each rail) forming a rectangle and the remaining point.

1.4 Acronyms and Abbreviations

The following acronyms and abbreviations appear in this document. They are defined as indicated:

AAR	Association of American Railroads
ABS	Automatic Block Signals
ADA	American Disabilities Act
AFI	Air Filter Institute
AFO	Audio Frequency Overlay
AISC	American Institute of Steel Construction
AISI	American Iron and Steel Institute
ANSI	American National Standard Institute

APC	Automatic Passenger Counter
API	Automatic Passenger Information (system)
APS	Auxiliary Power Supply
APTS	Advanced Public Transportation System
APTA	American Public Transit Association
AREA	American Railway Engineering Association
ARI	Air Conditioning and Refrigeration Institute
ASA	Acoustical Society of America
ASCII	American Standard Code for Information Interchange
ASHRAE	American Society of Heating, Refrigeration and Air Conditioning Engineers
ASIC	Application Specific Integrated Circuit
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
AVL	Automatic Vehicle Locator
AWG	American Wire Gauge
AWS	American Welding Society
BLS	Bureau of Labor Statistics
CDA	Copper Development Association
CDRL	Contract Deliverables Requirements List
CFE	Customer Furnished Equipment
CFR	Code of Federal Regulations
CMOS	Complementary Metal Oxide Semiconductor
DB	Dry Bulb
DIN	Deutsche Industrie Norm (German Industrial Standard)
EB	Emergency Brake
ECU	Electronic Control Unit
EIA	Electronic Industries Association
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
EN	European Norm (European Standards)
ESS	Energy Storage System
FAA	Federal Aviation Administration
FCC	Federal Communications Commission
FEA	Finite Element Analysis

FRA	Federal Railroad Administration
FTA	Federal Transportation Administration
GPS	Global Positioning System
HSCB	High Speed Circuit Breaker
HVAC	Heating, Ventilating, and Air Conditioning
ICEA	Insulated Cable Engineers Association
IEC	International Electrotechnical Committee
IEEE	Institute of Electrical and Electronic Engineers
ISO	International Standards Organization
JEDEC	Joint Electronic Device Engineering Council
JIC	Joint Industrial Council
LAHT	Low-Alloy, High-Tensile Strength (Steel)
LED	Light Emitting Diode
LVPS	Low Voltage Power Supply
MIL	U.S. Military Specification
MOV	Metal Oxide Varistor
MB	Maximum Brake
MC	Master Controller
MCDT	Mode Change Dead Time
MSB	Maximum Service Brake
MTBF	Mean Time Between Failure
MTP	Master Test Plan
MTTR	Mean Time to Repair
NBS	National Bureau of Standards
NEC	National Electrical Code
NEMA	National Electrical Manufacturer's Association
NFL	No Field Lubrication
NFPA	National Fire Protection Association
NTP	Notice to Proceed
OCS	Overhead Contact System
PA	Public Address
PI	Passenger Intercom
PIV	Peak Inverse Voltage
PTU	Portable Test Unit

QA	Quality Assurance
QAP	Quality Assurance Plan
QC	Quality Control
QCIP	Quality Control and Inspection Plan
RFP	Request for Proposal
RMS	Root Mean Square
ROW	Right of Way
SAE	Society of Automotive Engineers
SDOT	Seattle Department of Transportation
SHA	Safety Hazards Analysis
SI	International System of Measurement
SIC	Standard Industrial Code, U.S. Department of Labor
SSP	System Safety Program
t	Time
TIG	Tungsten Inert Gas
TIR	Total Indicated Runout
TOR	Top of Rail
TWC	Train to Wayside Communication
UL	Underwriter's Laboratories, Inc.
USASI	United States of America Standards Institute
USDOT	United States Department of Transportation
v	Velocity
VPI	Vacuum Pressure Impregnation
VSWR	Voltage Standing Wave Ratio
WB	Wet Bulb

1.5 Units of Measure

A	Ampere
dB	Decibel
dBA	Decibel on the 'A' weighted scale
dBm	Decibel milliwatt
g	Acceleration due to Gravity (9.81 m/s^2)
g	Gram
h	Hour
Hz	Hertz

J	Joule
kg	Kilogram
kgf	Kilogram force
km	Kilometer
km/h	Kilometers per hour
kN	Kilonewton
kWh	Kilowatthour
l	Liter
m	Meter
mg	Milligram
MHz	Mega Hertz
MPa	Mega Pascal
min	Minute
mm	Millimeter
mV	Millivolt
µV	Microvolt
N	Newton
Pa	Pascal
s	Second
V	Volt
Vac	Volt alternating current
Vdc	Volt direct current
^{o}C	Degree Celsius

1.6 CDRL

No submittals are required for this Section.

END OF SECTION

SECTION 2

DESIGN AND PERFORMANCE CRITERIA

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SECTION 2

DESIGN AND PERFORMANCE CRITERIA

2.1 General Vehicle Configuration

2.1.1 Vehicle Type

The vehicle shall be a double articulated, modern urban streetcar with contemporary styling, with the following characteristics:

- There shall be three body sections including a low floor (350 mm) center section.
- Not less than 50% of the vehicle shall be low floor. SDOT will consider a 100% low floor car.
- There shall be at least two doorways per side in the low floor section, of which at least one shall be double width and ADA compliant
- One door per side in the low floor section of the vehicle shall be equipped with an ADA compliant platform bridging device.
- The vehicle shall be capable of bi-directional operation, with a fully functional cab at each end. Operating control and performance shall be equal from both cabs.
- The vehicle shall be designed for single unit operation with provisions for towing a non-operable vehicle.
- Seating shall generally be arranged laterally in a two by one configuration.
- The vehicle shall be heated and air conditioned consistent with the Seattle environment and these Technical Specifications.
- The vehicle design shall incorporate an onboard energy storage system, i.e. a battery and/or capacitor drive system, which shall provide capability for wireless operation in accordance with these Technical Specifications.

2.1.2 Compatibility with Existing City Systems

The streetcar system will be an integral part of Seattle's existing transportation system. As such, the vehicle must include systems that are functionally and physically compatible with interfaces external to the vehicle. These are:

- Automatic Vehicle Locator (AVL)
- Automatic Passenger Counting (APC)
- Video Surveillance
- Radio (SDOT-furnished equipment)
- Traffic Light Priority
- Train to Wayside Communications (TWC)
- Automatic Passenger Information System (APIS)

General details of each system appear in other sections of this specification. Specific details are available from SDOT and the equipment manufacturers. Note that some interfaces and functionality may be proprietary, or may be difficult to fully acquire and define within the schedule. As such, it is likely that most of these requirements can be met only by employing the same equipment as presently used in Seattle.

Where alternative suppliers are proposed, formal demonstrations of compatibility and approval by SDOT are required, and this must be scheduled and completed at a date early enough to not affect vehicle delivery. SDOT will not consider any alternative proposals that require significant research and development time. Alternative equipment proposed by the Contractor is subject to all requirements of this contract.

SDOT will assist the contractor in defining any City-specific functional aspects of the equipment that is not inherent in the base designs, including specific model and part numbers, equipment manufacturer's contact persons, and similar information.

The vehicle shall be delivered with all City-specific functionality installed, unless otherwise agreed.

The Contractor is not responsible for warranties on City-specified equipment beyond those warranties provided by the original equipment manufacturer. The Contractor is not responsible for the reliability or maintainability of such equipment, if installed per the manufacturer's requirements.

The Contractor is responsible for installing the equipment per the manufacturer's requirements, and is responsible for any damage or mishaps that may occur prior to delivery of the vehicle to SDOT.

The Contractor shall review all physical interface requirements for this equipment, as provided by the equipment manufacturer, and advise SDOT of any conflicts between equipment requirements and specified vehicle requirements.

The Contractor is responsible for providing electrical power to the equipment with characteristics as required by the equipment manufacturers. This may require dedicated power supplies, which shall be provided by the Contractor. Note that the vehicle does not use the chassis as a negative return, and using the chassis as a negative return will similarly not be permitted for this equipment.

2.1.3 Elderly and Handicapped Accessibility

At least one double-leaf door per vehicle side will be equipped with an ADA-compliant platform bridging device for wheelchair access.

Space for at least two wheelchairs shall be provided in each vehicle, adjacent to the doorways with the bridging devices. Stanchions, grab bars, and handrails shall be provided to permit safe use of this area by standees when no wheelchairs are present.

Other ADA requirements (as they apply to transit applications), such as signage and information displays, shall be incorporated.

2.2 Operating Environment

2.2.1 Right of Way Description

The vehicles will be operated on city streets in mixed traffic with typical maximum speeds of 48 km/h, and with occasional top speeds of up to 70 km/h.

Station stops will occur on curb extensions which will be sized to accommodate the double-leaf doors and bridgeplates of the vehicle, but may not extend the entire length of the vehicle.

2.2.2 Right of Way Design Constraints

The physical constraints of the track, yard and wayside are included below. No warranty is made by SDOT that track will be maintained in its new condition.

Rail Types:	115 RE and Ri52N/Ri59
Minimum horizontal curve radius:	18 m
Minimum vertical curve radius, crest:	350 m
Minimum vertical curve radius, sag:	350 m
Track gage:	1435 mm
Average track superelevation:	25 mm
Maximum track superelevation:	75 mm
Maximum sustained gradient:	9.02%
Reverse vertical curves:	Either a crest and a sag of 250 m separated by a tangent section of 7.5 m or a crest and sag of 350 m separated by no tangent track.
Compound curves:	An 18 m horizontal curve superimposed on a 450 m vertical crest or sag.
Platform heights:	250 mm

2.2.3 Clearance and Fordability Requirements

Vertical under-car clearance is defined from TOR with the maximum suspension deflection and carbody roll, minimum vertical curve radius, maximum track superelevation, and fully worn wheels. Minimum vertical clearance shall be 50 mm.

Clearances between truck components and the carbody shall be as specified in Section 11.

The Contractor shall submit for review the dynamic vertical and horizontal excursions of the vehicle under normal and worst case conditions of truck and suspension motions and carbody roll.

The vehicle shall operate without impairment or damage in standing water of depths up to 75 mm.

2.2.4 Climatic Conditions

The vehicle shall operate as specified, and be stored and maintained without impairment, under all climatic conditions of the Seattle area.

Historical climate data for the general Seattle area are presented below. Actual temperatures and conditions local to the vehicle along the ROW, including those within, underneath, and above the vehicle, may be much more severe than the ambient climatic conditions, and the vehicle shall accommodate all such environmental extremes.

Climatic data for the Seattle area are as follows:

- Ambient air temperature, external to the vehicle

  - Nominal Minimum: -18°C
  - Nominal Maximum: 38°C
  - Mean:
    - January: 9°C
    - July: 25°C
    - Year: 12°C

  - Historical Extreme: Low -20°C
    High 38°C

- Relative Humidity Range: 50% to 87%
- Precipitation
  - Average annual rainfall: 965 mm
  - Maximum monthly rainfall : 330 mm
  - Maximum daily rainfall: 66 mm
  - Maximum daily snowfall: 150 mm
- Wind Speed
  - Maximum 1 minute gust: 56 km/h
  - Maximum wind gusts: 96 km/h

2.3 Supply Voltages

2.3.1 Overhead Catenary System Voltage

The vehicle shall operate at a nominal Overhead Catenary System (OCS) voltage of 750 Vdc, generated by 6- or 12-pulse rectification, with an operating range of 500 Vdc to 925 Vdc.

2.3.2 Low Voltage DC

A low voltage dc system, with battery back-up, shall be provided for vehicle controls and other specified equipment.

The low voltage dc system shall be 24 Vdc nominal, as defined in IEC 60571 section 3.1.1. All equipment operating from the low voltage dc system shall operate without damage at any voltage in accordance with IEC 60571 section 3.1.1.1. The equipment shall be rated for continuous operation at 28 Vdc, compliant with the rated voltage defined in IEC 60571 section 3.1.1.1.

Also see Section 9.

2.3.3 AC Supply Voltage

A source of 3 phase ac and single phase ac power shall be provided for loads specified elsewhere.

The 3 phase ac system source voltage may be 208, 460, or 480 Vac, 60 Hz. Other 3 phase voltages may be approved with technical justification. All ac loads shall be designed for the voltage at the load point.

The single phase ac source shall be 120 Vac, 60 Hz.

All equipment operating from the ac system shall operate without damage at any voltage within the worst case regulation limits of the APS (Reference Section 9), including all transient or controlled voltage outputs from the APS, and including the level of harmonic distortion present in the output waveform.

2.3.4 Transients and Abnormal Electrical Conditions

The vehicle shall provide protection against, and withstand without damage, all transients and voltage surges typical of rail transit, and as specified in IEC 60850 and IEC-61287.

All equipment on the vehicle shall be protected from damage or continued shutdown caused by random interruptions of the overhead contact wire system power due to isolation gaps, pantograph bounce, or other conditions.

All propulsion equipment shall be designed and tested for rated performance as described elsewhere in this section. The equipment shall operate over the range of 525 Vdc to 925 Vdc without damage, failure of the equipment to function as specified, or reduction of required service life.

All auxiliary equipment operated directly from the line voltage shall be rated for full performance at line voltages of 525 Vdc to 925 Vdc.

2.4 Vehicle Weights and Dimensions

The dimensions shall be as indicated below. Construction tolerances of dimensions shall be as stated on the Contractor's drawings unless specifically stated in this specification.

2.4.1 Weights

The weight of each vehicle, including passengers at 70 kg each, shall be defined as follows:

AW0: Empty vehicle operating weight.

AW1: Full seated load (passengers plus operator), plus AW0.

AW2: Standees at 4 persons per m^2 of suitable standing space per passenger, plus AW1.

AW3: Standees at 6 persons per m^2 of suitable standing space per passenger, plus AW1.

AW4: Standees at 8 persons per m^2 of suitable standing space per passenger, plus AW1.

All weights above are based on a ready-to-run vehicle, complete in all respects with all equipment, materials and fluids. Suitable standing space shall include all areas of the aisles where it is possible for passengers to stand. The ratings of vehicle equipment and systems shall be based on the actual weight and passenger capacity of the vehicle. The Contractor shall provide a plan view of the vehicle showing standing space and the calculations for each of the weights above.

AW0 vehicle maximum weight shall be 1,550 kg/m of length.

Wheel and axle loadings are restricted per the following:

- Wheel loadings within the same truck shall not vary by more than 10%
- Axle loading between trucks of same type shall not vary by more than 10%

2.4.2 Carbody Dimensions

Allowed vehicle lengths: 20 m to 22 m

Allowed vehicle width	2460 mm
Maximum low floor height above TOR	360 mm
Minimum interior ceiling height	1900 mm
Minimum side door opening width	700 mm, single leaf door
	1220 mm, double leaf door
Minimum side door opening height	1950 mm
Maximum static suspension deflection, from AW0 to AW3, as the sum of resilient wheel, primary and secondary suspension deflection	50 mm

2.4.3 Pantograph Dimensions

Maximum height above TOR in the lockdown position, new wheels, vehicle at AW0 passenger weight	3800 mm
Pantograph operating height under dynamic conditions, vehicle weight from AW0 to AW3, and with new to fully worn wheels	
Minimum Height	3950 mm
Maximum Height	6950 mm
Collector width over horns	1700 mm
Minimum carbon shoe length	1050 mm
Maximum longitudinal distance from vehicle pivot point centerline to center of pantograph shoe, locked down	50 mm

The pantograph location on the carbody, combined with pantograph head and carbon dimensions, shall provide for optimum operation and current collection under all conditions on the Seattle alignment.

2.4.4 Wheel Dimensions

Nominal Diameter, new	600 mm to 610 mm
Fully worn diameter	520 mm to 530 mm
Wheel Profile	Wheel profile shall be as recommended by the vehicle manufacturer to provide stable operation, and minimum wheel wear and noise, on the Seattle track design
Back-to-Back Dimension	1367 mm

2.5 Performance Requirements

Specified performance shall be independent of wheel wear, climatic conditions, and vehicle weights, unless otherwise indicated.

Performance in dynamic braking shall be available at all line voltages down to, and including, zero volts, assuming line voltage is present at initiation of braking.

Performance in all friction braking modes shall be available at all line voltages down to, and including, zero volts.

2.5.1 Load Weighing

The tractive efforts produced by the propulsion and braking systems shall be apportioned on a per truck basis according to the vertical load on each truck, such that tractive efforts are optimized for available adhesion.

2.5.2 Propulsion and Braking Assumptions

All propulsion and braking equipment shall be designed to interface properly and produce the required performance values. The basis for performance calculations, designs and evaluation shall be as follows:

- All acceleration, braking and jerk rates shall be based on level tangent dry track in still air except when otherwise noted.
- Propulsion equipment shall provide required performance at nominal 750 Vdc catenary voltage except as described below.
- Initial acceleration rates shall be as required by this section over a 600 Vdc to 925 Vdc range at the OCS.
- Braking rates shall be independent of the OCS voltage and once initiated, full dynamic braking capabilities shall be available without OCS voltage present.
- All specified performance capabilities shall be provided over the specified full range of the following:
    - Wheel wear
    - Ambient temperatures
    - Low voltage power supply voltage

2.5.3 Acceleration Requirements

Specified acceleration performance shall be available at the nominal line voltage and higher, and at AW2 or lower.

Acceleration requirements are:

Acceleration rate at MC Max Power:	1.34 m/s^2, $\pm$ 5% from 0 to 32 km/h
Time to reach 40 km/h from 0 km/h:	less than 10 seconds
Time to reach 70 km/h from 0 km/h:	less than 25 seconds

At weights greater than AW2, acceleration may be reduced in direct proportion to the ratio of AW2 weight/actual vehicle weight.

For line voltages less than nominal, the specified acceleration shall be provided except that the speed to which the acceleration is maintained may be reduced in direct proportion to line voltage/nominal voltage.

2.5.4 Speed Requirements

The vehicle shall have at least 10 kN of motoring tractive effort remaining at 70 km/h, over the specified range of wheel wear, at nominal line voltage, and at AW2 loading.

Minimum safe operating speed for all equipment with fully worn wheels shall be at least 80 km/h.

2.5.5 Braking Requirements

Normal service braking shall be a combination of dynamic braking and friction braking.

Dynamic braking shall dynamically blend resistive and regenerative braking. The control methods shall maximize regenerative braking within the braking voltage limits specified elsewhere.

At all vehicle weights, service braking shall be 100% dynamic braking down to the dynamic brake fade point.

In the event of dynamic brake failure on a truck, friction brakes shall automatically provide the necessary braking efforts to achieve the requested rate.

The MSB average braking rate requirements, as measured by the entry speed divided by stopping time, are:

- 1.34 m/s^2 $\pm$5%, with all dynamic brakes functional, from any entry speed to zero
- 1.34 m/s^2 $\pm$10%, with one or more dynamic brake units inoperative, from any entry speed to zero. After the initial stop with a dynamic brake failure, the system may automatically reduce vehicle maximum speed to conform to friction brake thermal limitations.

The instantaneous variation in braking rate shall not exceed $\pm$10% of the command value in blended braking and $\pm$20% in friction brake only braking, at any speed.

Dynamic brake fade shall occur at 5 km/h or lower.

Maximum Brake (MB) is defined as a high rate service brake plus track brake. The MB average brake rate requirements, as measured by the brake entry speed divided by stopping time is:

- 2.25 m/s -0% +30%, from any speed to zero, for all vehicle weights

2.5.6 Emergency Braking Requirements

Application of emergency braking shall be from the console emergency push button switch.

Emergency braking shall be a combination of, friction disc brakes, track brakes, dynamic brakes, and the application of sand. The minimum emergency brake rate at AW0 shall be achieved independently of dynamic braking, using friction disc brakes, track brakes and the application of sand. At vehicle weights above AW0, dynamic brakes shall supplement the friction disc brakes, track brakes and application of sand, so the minimum emergency brake rate can be achieved. The spin/slide system shall be cut out during emergency braking.

The minimum emergency braking performance requirement is 2.25 m/s^2, average, from any speed to zero, for all vehicle weights.

Emergency braking shall not be jerk limited, and shall not be inhibited by the state of any other vehicle systems.

An emergency brake command shall be irretrievable to the no motion detection speed. Track brakes shall be released and sanding terminated when the vehicle achieves no-motion.

Emergency brake is considered a safety system. Emergency braking shall be controlled by a double wire double break control line (separate positive and negative control wires with duplicate switching contacts for each control function in the positive and negative control lines).

See Section 5 for additional emergency brake control requirements.

2.5.7 Wheel Spin Slide Correction

A system shall be provided to detect and correct wheel spin and slide on all wheels of the vehicle, both in acceleration and braking. The spin/slide system shall be designed for safe operation such that a spin/slide system failure must not prevent the application of braking at any level less than desired, in any braking mode.

- The spin/slide system shall detect both individual and synchronous slides or spins by evaluation of axle or wheel speed differences and acceleration/ decelerations.
- The spin/slide system shall use the speed information from all axles (wheels) of the vehicle to establish an accurate vehicle speed.
- Spin/slide correction shall use modern methods of tractive effort modulation that are in the same proportion to the magnitude of the detected spin or slide.
- The system shall modify the deceleration detection level during track brake applications.
- 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.
- Removal of effort shall not be jerk limited during spin/slide corrections.
- The wheel spin/slide correction system shall function properly with differences of up to 50 mm in diameter among the wheels of one truck compared to the wheels of the other truck of a vehicle.
- The slide detection system shall include a safety supervision to override the brake release on a per truck bases if a slide condition is considered to be excessive. This slide supervision algorithm shall be submitted to SDOT for approval.
- Spin/slide protection shall be active in all motoring and braking modes except for emergency braking, or as indicated in Section 5, or as indicated elsewhere in these Technical Specifications.
- Spin/slide efficiency shall be at least 90%, as measured by an inertial accelerometer on artificially wetted rails. Efficiency shall be calculated as the ratio of actual acceleration to achievable acceleration, using an approved calculation method. Measurements shall be taken only during periods of actual spin/slide activity when wheels are spinning or sliding.

2.5.8 Jerk Limits

The rate of change in acceleration during all requested changes in power and brake efforts shall be actively limited to 2.0 m/s^3, or other agreed value.

Where the rate of change request is less than the jerk limit, the system shall follow the command signal rate of change within specified accuracy limits.

- The jerk limits specified shall apply to all normal power and service braking applications
- Release of power when traversing overhead primary power isolation gaps need not be jerk limited; however, reapplication of power shall be jerk limited
- Emergency brake applications shall not be jerk limited
- Release of power, when the master controller is moved directly from a power position to a brake position without stopping in the coast position, shall not be jerk limited; however, the application of the service braking portion of the mode transition shall be jerk limited
- Friction brake release at less than 5 km/h shall not be jerk limited

2.5.9 Mode Change Dead Times

The mode change dead time (MCDT) shall be less than 400 ms for the following direct mode changes:

- Power to Brake
- Power to Coast
- Coast to Brake
- Coast to Power
- Brake to Coast
- Brake to Power below 5 km/h

For the direct mode change Brake to Power, above 5 km/h, the mode change dead time shall be less than 800 ms.

Mode change dead times for EB applications shall be 400 ms or less, regardless of the original mode.

Mode change dead time shall be measured from the time that the control line(s) change(s) state until the vehicle acceleration or deceleration is reduced to 90% of the previously commanded value, or 10% of the new commanded value, respectively, for mode changes to or from coast, and until it reaches 10% of the new commanded value for mode changes between brake and power.

2.5.10 No Motion Detection

Equipment shall be provided to detect all vehicle motions down to, and including, 2 km/h.

The speed detection system shall generate a safe signal, indicating that no-motion has been detected, for other vehicle systems that require such information.

The no-motion detection system shall monitor all axles, and shall include at least 2 independent circuits to generate the no-motion state.

2.5.11 Rollback Prevention

The propulsion and braking systems shall be configured, and have sufficiently precise controls, to prevent the vehicle from rolling in a direction opposite to that selected by the reverser.

When accelerating from a stop, the vehicle controls shall prevent vehicle rollback until motor torque is sufficient to hold or move the vehicle.

When moving the MC to a coast position from motoring, the vehicle shall detect and prevent rollback either by maintaining motor torque to hold the vehicle at zero speed, or by applying friction brakes upon detection of reverse motion. In either configuration, an AW3 vehicle shall not roll backwards more than 400 mm or exceed a speed of 1.5 km/h on any specified grade.

2.5.12 Parking Brake

A parking brake shall be provided on all powered trucks. The parking brake shall automatically apply when the vehicle is powered-down from the cab, or when the friction brake system loses system pressure or the ability to stop the train normally.

The parking brake shall be capable of stopping and holding a vehicle at all weights up to AW4 on a maximum grade of 10%.

2.5.13 Duty Cycle Rating

The vehicle shall operate on the intended alignment, under worst case ambient conditions, without exceeding the thermal ratings of any equipment, as follows:

- The vehicle shall be capable of operating continuously at AW3 passenger loading on a duty cycle comprised of full power acceleration to the maximum speed limit for each track segment, except as noted below, maintaining that speed until brake, full service deceleration to a stop, and 10 second dwell time at each station, over the specified alignment, in all directions, with a 2 minute layover at each end of the line.
- The duty cycle above shall include operating over track segments, using the Onboard Energy Storage System as defined in Section 2.6
- An operating vehicle shall be capable of towing or pushing an inoperative vehicle with the brakes released (not functional). Full acceleration and braking tractive effort shall be available on the operative vehicle, except reduced acceleration is permitted within the wireless segments. An operative vehicle at AW2 weight or less shall have the capability to tow (push/pull) an inoperative vehicle at AW0 weight to the station at the beginning of the next wireless segment, then after deboarding passengers, the operative vehicle at AW0 shall be able to tow the inoperable vehicle to the shop, via the worst case (most severe duty cycle) routing.
- The vehicle shall be capable of continuous operation at any speed from 3 km/h to 70 km/h at AW3 on any portion of the streetcar line without equipment overheating or damage.

2.5.14 System Redundancy and Recovery

The vehicle shall be configured such that it can continue to operate under failure conditions. Devices and procedures shall be provided to disable the failed system and allow the remaining

systems to continue operation. Performance may be limited, except where specifically indicated otherwise.

The following systems shall be physically and functionally redundant and share no components except where specifically permitted:

- Propulsion
- Friction Braking
- HVAC
- AC and DC Power Sources (see Section 9 for allowed alternative arrangements)

Specific requirements for each system are provided elsewhere in this document.

The vehicle shall also have the ability to operate for limited distances and with limited performance under battery and/or capacitor power. See Sections 2.6 and 10.

2.6 Onboard Energy Storage System

2.6.1 Performance Requirements

The vehicle shall incorporate an onboard energy storage system (OESS) which shall be capable of providing propulsion and auxiliary power during wireless operation to meet the following requirements and conditions:

- Initiating the below wireless operation with an OESS that is no more than 80% fully charged
- Providing a maximum acceleration rate of at least 1.0 m/s^2 at AW2
- Achieving a maximum speed of at least 32 km/h
- Operating over the SDOT First Hill Streetcar alignment, 20 trips per day, with the following wireless segments

  Outbound - Pioneer Square Terminus (10+00) to the Station at Jackson and 5^{th}, (23+00), approximately 0.4 km

  Outbound - Station at Broadway and Pine (127+00) to the Capitol Hill Terminus (141+00), approximately 0.43 km

  Inbound - Station at Jackson and 7^{th} (33+00) to the Pioneer Square Terminus, (10+00), approximately 0.7 km
- Assuming stopping at each stoplight and station for 20 seconds
- Providing normal service braking and emergency braking in accordance with this Section 2 except that top speed may be limited to at least 32 km/h
- Providing normal spin/slide, jerk limits, MCDT, no motion detection, and rollback prevention requirements in accordance with this Section 2
- Providing normal operation of all low voltage circuits and functions, with HVAC in ventilation mode
- Onboard energy storage system shall have a minimal life of 10 years.
- Providing at least 6 kWhr of energy to traverse the wireless segment

- Completing the above wireless operation with an OESS that is at least 40% charged

2.6.2 Charging and Discharging

As discussed in Section 10, the OESS shall be charging whenever the pantograph is connected to the energized OCS or the car is in regenerative braking. In wireless segments, the OESS shall be charging whenever the car is in regenerative braking.

The OESS shall be capable of being charged, without damage, from a 30% charged state to an 80% charged state within a maximum of 10 minutes when the car is at a stop, with auxiliaries running, and connected to the OCS with a voltage range of 600 Vdc to 925 Vdc.

2.7 Noise and Vibration

2.7.1 General

All sound measurements shall be performed using Type 1 sound level meters meeting current IEC or ANSI standards. Sound levels shall be measured on the A scale (dBA), with slow meter response for stationary vehicle measurements, and with fast meter response for moving car measurements.

The maximum allowable noise level shall be reduced by at least 3 dB if significant pure tones in the range from 250 Hz to 8,000 Hz are present in the noise. Pure tone noise shall be considered significant in this context if any one-third octave band sound pressure level is 3 dB, or more, higher than the arithmetic average of the 2 adjacent bands containing no pure tones.

Unless otherwise noted, specified noise limits shall be for equipment which operates on a regular basis and shall not apply to equipment which operates infrequently, such as a circuit breaker or pneumatic pressure relief device. Contractor will be required to provide all noise and vibration test equipment necessary to perform the tests.

2.7.2 Interior Noise

Measurements of interior noise levels shall be taken in accordance with ISO 3381.

With the vehicle stationary with windows and doors closed, air conditioning equipment operating in full cool, with all auxiliary equipment operating simultaneously under normal operating conditions, the interior noise level shall not exceed 68 dBA.

With the vehicle stationary with windows and doors closed, with the air conditioning equipment operating in cooling mode, the cab noise level at a seated operator’s ear height shall not exceed 65 dBA.

With the vehicle operating on the Seattle alignment, on smooth rail, at any speed up to 56 km/h and under any acceleration or deceleration condition, interior noise shall not exceed 75 dBA.

Noise generated by fluorescent lamps, fixtures, and ballasts installed and energized at rated voltage and frequency, measured 300 mm from any lighting fixture, shall not exceed 48 dBA.

2.7.3 Wayside Noise Limits

All measurements of exterior noise levels shall be made in accordance with ISO 3095, with microphones placed 7.5 m from the track centerline, and 1.5 m above top-of-rail.

With vehicle stationary and empty, air conditioning equipment operating in full cool and all auxiliary equipment operating simultaneously under normal conditions, exterior noise shall not exceed 70 dBA.

With the vehicle operating on the Seattle alignment, on smooth rail, at any speed up to 56 km/h, under any acceleration or deceleration condition, exterior noise shall not exceed 75 dBA.

2.7.4 Vibration Generation

Vehicle equipment operation shall not cause visible or audible vibrations anywhere on the vehicle floor, walls, ceiling panels and seat frames, at any specified operating speed, and under any acceleration or braking condition except emergency braking.

Interior vibration limits are as follows:

- Below 1.4 Hz: Maximum deflection (peak-to-peak) of 2.5 mm
- 1.4 Hz to 20 Hz: Peak acceleration of 0.1 m/s^2
- Above 20 Hz: Peak velocity of 0.75 mm/s

2.7.5 Vibration and Impact Loads

All vehicle equipment shall operate without damage or degradation of performance when subjected to vibration and impacts encountered during normal service, and the following:

- Car body mounted components shall withstand vibrations up to 0.4 g peak-to-peak at frequencies up to 100 Hz, and impact loads of 1 g lateral, 2 g vertical, and 3 g longitudinal. Designs qualified to EN 12663 will also be allowed.
- Truck frame mounted components shall withstand vibrations up to 4 g peak-to peak at frequencies up to 100 Hz, and impact loads up to 10 g each applied individually on any major axis
- Truck axle mounted components shall withstand vibrations up to 10 g peak-to peak at frequencies up to 100 Hz, and impact loads up to 40 g each applied individually on any major axis

2.8 Ride Quality

Ride quality shall be evaluated according to the latest ISO 2631 as applicable to the rail vehicle design. The root mean square (rms) acceleration values for each measurement point shall not exceed 0.32 m/s^2 for operators, seated and standing passengers. Also the vibration total value (root sum of squares summation) for each measurement point shall be calculated, and shall not exceed 0.5 m/s^2. Where appropriate, frequency weighting, Wb, shall be used instead of Wk. Acceleration data shall be evaluated over the range of 0.5 Hz to 80 Hz.

2.9 Electromagnetic Interference and Compatibility

The vehicle equipment shall not create electrical interference with other equipment on the vehicle, nor with equipment on the wayside.

The vehicle shall comply with EN 50121 for railway applications, except as indicated below.

2.9.1 Radiated Emission Limits

Radiated emissions shall be in accordance with the recommendations of EN 5021-3-1.

2.9.2 Conductive Emission Limits

Measurement procedures and terminology for conductive emissions shall follow UMTA-MA-06-0153-85-11. The conductive emissions shall be limited to the following:

- From 0 Hz to 40 Hz, 10A maximum
- From 40 Hz to 120 Hz, 2 A maximum
- From 120 Hz to 320 Hz, 10 A maximum

2.9.3 Inductive Emission Limits

Measurement procedures and terminology for inductive emissions shall follow UMTA-MA-06-0153-85-8. The inductive emissions shall be limited to a maximum of 20 mV, rms, rail-to-rail, at all frequencies between 20 Hz and 20 kHz. This condition shall be met by each individual power equipment as well as the simultaneous operation of all equipment.

2.10 Vehicle Safety Analysis

2.10.1 General

The streetcar shall be designed and constructed to be safe to passengers, persons nearby, and streetcar employees, both under normal operating conditions, and in the event of equipment failure. Contractor shall insure that all systems' safety aspects have been considered for each individual system, and for systems integrated to complete the vehicle design.

2.10.2 General Safety Design Requirements

The term ‘hazard’ describes any real or potential condition that can cause injury, death or damage to or loss of equipment or property. Hazards shall be resolved such that the likelihood of any such injury or damage shall be remote or improbable.

The following guidelines, listed below, shall be incorporated into the design of all vehicle systems affecting safety:

- Only components with high reliability and predictable failure modes, and which have been proven in conditions similar to the projected service, shall be utilized.
- All electronic circuits shall be assumed capable of failing in permissive modes.
- Software shall be considered unsafe unless it is verified as safe by an approved methodology. Approved methodologies shall comply with the requirements of IEEE 1483 and/or EN 50128.
- Systems shall be based on closed circuit principles in which energized circuits result in permissive conditions, while interrupted or de-energized circuits result in restrictive conditions.
- All vital circuits not wholly within the system apparatus enclosure shall be double-wire, double-break, with the exception of connections to non-vital circuits, which may be single-wire, single-break.
- Any component or wire becoming grounded shall not cause a permissive condition. Safety circuits shall be kept free of any combination of grounds that will permit a flow of current equal to, or in excess of, 75 % of the release value of any safety device in the circuit.
- Circuit impedances, signal encoding, shielding, layout, and isolation shall be selected to reduce the effects of interference to the extent that safety is maintained under all conditions.

- Commands that result in permissive conditions shall be propagated by no less than two independent signals, both of which must be present before the permissive condition can occur. The lack of either signal shall be interpreted as a restrictive command.
- Systems controlled by variable level signals shall be arranged such that zero signal level results in the most restrictive condition. At least one enabling signal, however, independent from the variable control signal, shall be present before the control signal can modulate the system to a more permissive level.
- Circuit breakers and fuses shall be guaranteed by the manufacturer to successfully interrupt rated currents. Circuit breakers and fuses shall be applied such that the maximum circuit fault currents cannot exceed the manufacturer's guaranteed operating ranges.
- Systems that rely on structural integrity for safety shall have sufficient safety factors such that failures are not possible within the life of the vehicle under all possible normal conditions.
- Systems and devices subject to wear shall not wear to permissive states within a period no less than three times the recommended and approved overhaul period under the worst-case combination of duty cycle, environment, and all other influences. Such systems and devices shall be clearly indicated as SAFETY CRITICAL in the maintenance manuals.
- Mechanical systems which apply force to achieve safe states shall not depend upon the application of fluid pressure or electrical energy, unless specifically approved.
- All locks, catches, and similar devices affecting safety shall be either self- engaging without application of power or, if engaged by application of power, shall remain fully and safely engaged in the absence of power.
- All systems shall function safely under all combinations of supply voltages, fluid pressures, shock, vibration, dirt accumulation, and the Seattle environment.
- All safety related systems, and devices within those systems, shall be clearly identified as SAFETY CRITICAL in all operation and maintenance manuals, procedures, and training materials.

2.10.3 Failure Induced Hazards

Vehicle equipment and systems shall be designed and constructed to revert to safe modes under failure conditions. 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 equipment, shall conform to both of the following design principles:

- The failure of a single device shall not result in a permissive condition; and,
- 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.

Failures in equipment 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 not be considered safe.

2.10.4 Fire and Life Safety

All vehicle components, subsystems, and systems shall be designed for the prevention of fire and protection of the public, employees, and emergency response personnel from injury due to fire, smoke, explosion, or panic due to these occurrences and protection of system elements from damage by fire or explosion.

The vehicle design shall provide for equipment to be located outside of the passenger compartment, whenever practical, unless specified otherwise, to isolate potential ignition sources from combustible materials. The articulation, floor, sides, and roof shall be designed to retard propagation of an underfloor and/or roof fire to the vehicle interior. Fire-stops shall be provided at floor and roof penetrations. Enclosures for control and other critical equipment shall be located to provide protection against environmental contamination and mechanical damage.

2.10.5 Safety Under Normal Operating and Maintenance Conditions

Passengers and operators shall not be exposed to tripping hazards, sharp points and edges, lethal or injurious voltages, toxic materials, abrupt or unexpected accelerations, or similar hazards. Location, illumination levels, colors, graphics, and surface finishes shall be selected to enhance visibility of step edges, windscreens, controls, and other objects with which the passengers and operators must interface.

Normal and emergency equipment and controls which the passengers or operators may operate shall be clearly identified, and where required, operating procedures shall be presented in both printed and graphic formats.

Maintenance manuals, procedures, and training shall indicate the proper handling, storage, and disposal of hazardous materials. Exposure of maintenance personnel to lethal or injurious voltages shall be reduced through compartmentalization, interlocks, and similar measures. All equipment shall be free from sharp points and edges. All equipment containing hazardous

materials, lethal or injurious voltages, or other risks shall be clearly labeled on both the outside and inside of the equipment.

Maintenance, operating, training, and other manuals shall clearly identify all hazardous materials and equipment. All maintenance procedures involving hazards shall contain clear identification of the hazard and instructions to reduce or eliminate the hazards during the procedure.

2.10.6 Human Error and Other External Influences

All systems shall protect against unsafe conditions resulting from human error. No sequence of operations, or the simultaneous activation of any controls, shall result in unsafe conditions. Where conflicting commands, such as simultaneous power and brake, are requested, the more restrictive shall result.

Maintenance of safety-related equipment shall be arranged such that the effects of errors are minimized. Methods such as limitation of adjustment ranges, unalterable software, non-interchangeable parts, and visible wear indicators shall be employed.

2.10.7 Hazard Identification

Contractor shall identify all failure-induced and normal operating (non-failure condition) hazards.

In addition to those hazards identified by the Contractor, the following hazards shall be included in the listings and shall be considered hazards:

- Emergency brake fails to apply when requested
- Service brakes fail to apply when requested
- Propulsion fails to cease when requested
- No-motion detection system indicates no-motion when vehicle is moving
- Door opens spontaneously when not commanded
- Door opens on the wrong side of the vehicle
- Door closes on person's limb and indicates door closed and locked to control system
- Door interlocks erroneously indicate door is closed and locked
- Excessive currents or overheated equipment cause fire
- Vehicle moves in wrong direction

2.10.8 Hazard Analyses

Contractor shall perform hazard analyses on all hazards identified in the hazard lists. Analyses shall demonstrate that the vehicle conforms to the requirements of this Specification and that all identified hazards are either eliminated, or reduced to levels of risk in accordance with Hazard Analysis Guidelines for Transit Projects - U.S. Department of Transportation, Federal Transit Administration document DOT-FTA-MA-26-5005-00-01.All hazard analyses shall be adjusted or amended as the vehicle design and construction progresses.
The analysis methods shall be selected by the Contractor as appropriate for the system under evaluation and the hazard severity, subject to approval by SDOT. Contractor shall be prepared to demonstrate, by test, the validity of any portion of all analyses.

Standard failure and safety analysis methods, and published failure rates for components, shall be utilized wherever possible.

Existing hazard analyses of like equipment operating under like conditions may be offered in lieu of performing a complete analysis of proposed equipment, subject to SDOT's approval.

2.11 Reliability

2.11.1 Requirements

Vehicle systems shall meet the Mean Time Between Failure (MTBF) requirements listed below, assuming maintenance, preventive and corrective, is performed as recommended by the Contractor.

Additional reliability requirements for specific equipment may appear elsewhere in this document.

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 5 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.

All equipment furnished by the Contractor shall be considered as belonging to one of the systems listed below. SDOT-furnished or -specified equipment is excluded from these requirements.

System	MTBF (hours per car)
Carbody & Appointments, including seating, windows, cab equipment	100,000
Propulsion, Dynamic Brake & Controls including gear case	20,000
Friction Braking, including track brake and sanders, and load leveling controls (if provided)	17,000
Communications and passenger information	40,000
Passenger Doors & Controls, including bridgeplates (if provided)	17,000
Lighting	100,000
Electrical, including the vehicle network and cab controls, and apparatus not included in other systems. Excludes equipment internal to other systems.	20,000
HVAC	30,000
Trucks & Suspension including load leveling suspension elements (if provided)	50,000

2.11.2 Reliability Demonstration Plan

A reliability demonstration plan shall be developed by the Contractor for approval by SDOT 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, and 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.

2.12 Maintainability

The vehicle shall incorporate design standards which minimize Mean Time To Repair (MTTR) and costs throughout its intended useful life.

The quantitative MTTR requirements for the car shall consist of the following subsystem requirements:

System Element	MTTR (hours)
Carbody & Appointments	2.13
Propulsion, Dynamic Brake & Controls	1.77
Friction Braking, including load leveling controls (if provided)	1.94
Electrical	1.50
HVAC	2.12
Communications (except CFE)	0.82
Passenger Doors & Controls, including bridgeplates (if provided)	0.84
Lighting	0.50
Couplers & Draft Gear	1.5
Trucks & Suspension, including load leveling suspension elements (if provided)	1.57
Total	14.7

The MTTR for each element shall be derived from Predicted Mean Time To Repair (PMTTR) analyses as required. SDOT may approve subsystem MTTRs which take more time than specified, provided the average for any system element is not changed significantly and total MTTR hours for the vehicle are not exceeded.

2.12.1 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 SDOT 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.

2.12.2 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.

2.12.3 Scheduled and Preventive Maintenance

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

The Contractor's reliability or maintainability demonstrations shall assume these service levels, with no augmentation.

The total of scheduled maintenance tasks shall be defined in the maintenance manual, and shall be no more frequent or take more time than the following schedule:

Operating Miles	Scheduled Maintenance in Hours
1,000	6
10,000	8
20,000	24
30,000	36
150,000	50
300,000	1200 (First Major Overhaul)

An exception is made for HVAC filter maintenance, which may occur at 5000 mile intervals, or greater.

Scheduled activities during the 10,000 mile cycle shall be limited to inspection, filter cleaning or replacement, and replacement of consumables.

SDOT will verify that the above schedule can be achieved 3 months after the acceptance of the first vehicle. This delay period is to enable the Contractor to ensure that all maintenance requirements for the car equipment have been effectively established by its operating and maintenance training programs and manual publications.

2.13 CDRL

The following submittals are required.

2-1 General arrangement drawings, including:

- 2-1-1 Plan, profile, and front elevation drawings of the vehicle exterior, showing all visible features, with dimensions
- 2-1-2 Plan view of seating arrangement, including seat dimensions and spacings, aisle widths, wheelchair and bicycle areas, doorway dimensions, etc.

2-1-3 Longitudinal section drawings of the vehicle, showing seating arrangements, stanchions, interior steps, cab, etc.

2-1-4 Plan view drawing of all roof equipment, with dimensions

2-1-5 Plan view drawing of under-floor equipment, including trucks, with dimensions

2-2 Capabilities of the vehicle on specified horizontal and vertical curve radii

2-3 Vehicle clearance dimensions on tangent track, showing effects of maximum suspension deflection and maximum body roll. Identify the location of the roll center(s).

2-4 Vehicle dimensions from Section 2.4.2, where not included in 2-1 above

2-5 Pantograph dimensions and operating ranges from Section 2.4.3

2-6 Wheel dimensions from Section 2.4.4, including a drawing of the recommended wheel profile

2-7 Truck dimensions not included in 2-1 above

2-8 Description of the load weighing scheme

2-9 Performance data, including:

2-9-1 Tractive effort curves for motoring from zero to 70 km/h, at AW0, AW1, and AW2, for line voltages of 525, 600, 750, and 900 Vdc

2-9-2 Braking performance curves, including emergency braking, from 70 km/h to zero, at AW0, AW1, AW2, AW3, and AW4 showing apportionment between dynamic, friction braking, and track brakes

2-9-3 Description of regenerative braking, voltage ranges, maximum currents, etc.

2-9-4 Speed / time / distance curves for motoring and braking at 750 Vdc and at AW0, AW1, AW2, AW3, and AW4

2-9-5 Description and circuit diagram of the emergency brake system. See Section 2.5.6

2-9-6 Description of the spin/slide system for motoring and braking

2-9-7 Slide control safety supervision algorithm

2-9-8 Description and circuit diagrams of the no-motion detection system

2-9-9 Description and capabilities of the parking brake system

2-9-10 Verification of the thermal capacity of the propulsion and braking equipment under the conditions described in Section 2.5.13. Submittal shall include all input assumptions, ambient temperature assumptions, speed/time/distance plots of the vehicle on the Seattle alignment, temperature predictions (or actual test results) for all equipment, including motor windings, brake resistors, brake discs, inverter and brake chopper device junction temperatures, and similar.

2-10 Description and analyses showing compliance of the ESS with the requirements of Section 2.6

2-11 Analyses, test results, and similar demonstrating compliance with EMI requirements of Section 2.9

2-12 Plans, documents, and analyses demonstrating that the vehicle is safe, and complies with Section 2.10. At a minimum, the following is required:

2-12-1 A system safety plan, delineating the steps and processes which will be used by the contractor to insure vehicle safety

2-12-2 A hazard listing, as described in Section 2.10.7

2-12-3 Failure analyses, both top-down and bottom-up, as appropriate and as approved, demonstrating that the hazards identified above will not occur

2-13 Other analyses, drawings, material property data sheets, or other information appropriate for demonstrating safety

2-14 Predicted reliability of all systems, with supporting data

2-15 Reliability demonstration plan

2-16 Predicted MTTR of indicated systems, with supporting data

2-17 Scheduled maintenance plan

END OF SECTION

SECTION 3

CARBODY STRUCTURE

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SECTION 3

CARBODY STRUCTURE

3.1 General

This section covers the performance requirements for the carbody structure and materials.

3.2 Materials

The carbody structure shall be constructed of aluminum, low-alloy high-tensile (LAHT) steel, stainless steel, or a combination thereof. Non-structural carbody exterior elements may be of glass fiber reinforced plastic or similar service-proven materials. The Contractor shall submit drawings showing materials used for all structural members including outside sheathing.

3.3 Structural Arrangements, General Requirements

The streetcar structure shall be unitized for each sub-body and may utilize the exterior skin as a stressed structural element. All portions of the carbody shall be provided with adequate venting and drainage to prevent the build-up of condensate. Enclosed structural cavities shall be vented and, if required, shall be treated with a rust proofing coating suitable for the vehicle design life.

Anticlimbers and a front end frame structure consisting of partial height collision posts at the approximate one-third points (horizontal plane) of the end frame, structural corner posts at each extreme carbody corner, and a horizontal beam ("structural shelf ") at the bottom of the windshield tying the tops of the collision posts to the corner posts, all securely welded to the end frame sheathing to resist telescoping in collisions. Equivalent anti-telescoping and crashworthy elements shall be provided at the articulation joint and support structure. Alternative structural arrangements with equal or better performance may be proposed.

If the front end of the car is formed from fiberglass reinforced plastic, the front end panel below structural shelf and between collision posts shall be reinforced with steel sheet so that proper protection to the operator is provided.

3.4 Structural Design Requirements

The structural design shall be based on proven rail vehicle techniques and elements and shall accommodate all structural static, dynamic, and fatigue loads encountered in revenue service. The carbody structure shall meet the requirements for Category IV of EN 12663, latest revision, unless otherwise noted in this specification. In the event that the carbody shell designed to other recognized standards is proposed, the Contractor shall provide all details of the standards used, evidence of compliance by analysis and test, and justification as to how the proposed design does not diminish the ability to protect passengers and operator in the event of accident under normal operating conditions.

In the event that the proposed car is designed to Crash Energy Management (CEM) per EN 15227 or other recognized standards, end structure on both front end and articulated end shall be designed to all possible load cases in this Section in accordance with the energy absorbing schedule adopted on the proposed car.

3.4.1 Vertical Design Load Strength Requirements

The completely equipped carbody shall be designed to carry the maximum loading of the vehicle weight AW4, less truck weight or running gear weight, distributed uniformly along the vehicle, with stresses not exceeding 65% of the guaranteed minimum material yield strength, and 65% buckling strength, and the allowable fatigue stress for joints and structural details which are fatigue critical.

For each joint design, the static stress at the AW2 load shall be less than the mean stress that determines the allowable fatigue limit.

The dynamic factor shall be as determined by the Contractor, but shall not be less than ±20%. The fatigue limit shall be established for 10 million cycles.

3.4.2 End Sill Compression Load

Under an end compression load of 400 kN, applied at the buffer level and/or the center line of the coupler, with the load path through the articulation section(s), the following conditions shall be met:

- Margin of safety shall be no less than 1.15 of the guaranteed minimum material yield strength and plastic buckling strength in any structural members, including sheathing.
- At no point inboard of the coupler anchor shall the margin of safety be less than the lowest margin of safety outboard of the coupler anchor.
- That structural element with the lowest margin of safety inboard of the coupler anchor shall not be located in any part of the articulation or the yoke arms which attach the carbody sections to the articulation.

3.4.3 Anti-Telescoping Load Above Floor

The capacity of each collision post, when loaded in a horizontal plane 1000 mm above the top of rail and within 15^{o} either side of the longitudinal axis of the vehicle, shall be a minimum of 80 kN with no yielding of any carbody structure. The posts and/or supporting structures in the end frame shall be designed such that when the post is overloaded, the initial failure shall begin as bending or buckling in the structure.

3.4.4 Anti-Telescoping Load at Floor

The minimum ultimate shear strength of each collision post shall be 250 kN when the load is applied at a point even with the top of the underframe to which the post is attached.

3.4.5 Structural Shelf

A horizontal structural shelf shall be provided below the windshield and shall connect the tops of the collision posts to the corner posts. The shelf shall be capable of supporting a longitudinal load of 80 kN applied anywhere along the span without permanent deformation of any part of the vehicle structure. The outer ends of the structural shelf shall be supported by the corner posts, which shall be attached to both the underframe and roof structures.

3.4.6 Corner Post, Horizontal Load

The capacity of each corner post, under an inward horizontal load in any direction from longitudinal to transverse, applied 1000 mm above the top of rail, shall be 40 kN with no yielding of any part of the vehicle structure. The connections of the posts to the supporting structure, and

the supporting structure itself, shall be strong enough to develop the bending capacity of the posts. If the posts are designed to support more than 40 kN, then the supporting structure must be strong enough to support the increased bending capacity of the posts. The posts shall fail before the supporting structure.

3.4.7 Corner Post, Shear Load

The ultimate shear strength of each corner post, in any direction from longitudinal to transverse, at the level of the top of the underframe or supporting structure shall be 78 kN.

3.4.8 Anticlimber Loads

The anticlimber shall withstand a vertical load of 1.1 times the static load required to raise the end of the vehicle, with the truck or running gear attached, combined with a longitudinal compressive load applied at the carbody centerline of 60% of the end strength, with no failures of the anticlimber, supporting carbody structure, or intervening connections. In the event that the proposed car is not equipped with anticlimber, the Contractor shall demonstrate alternative means to resist from climbing during head end collision.

3.4.9 Articulation Joint Anticlimber Loads

The articulation joint shall withstand the resulting forces of a vertical load of 1.1 times the static load required to raise the end of the vehicle combined with a longitudinal compressive load applied at the carbody centerline of 60% of the end strength, with no structural failures which may result in telescoping of the vehicle sections.

3.4.10 Floor Load

The following conditions shall be met for a fully equipped vehicle with a vehicle weight of AW4, evenly distributed:

- The floor panels shall not deflect more than 1/250 of the shortest span between supports, up to a maximum of 5 mm.
- The floor beams shall not deflect more than 1/250 of the span between supports.

The maximum stress in the floor beams shall be less than 65% of the critical buckling stress, or 65% of the yield strength of the material, whichever is less.

3.4.11 Roof Load

All parts of the roof structure and walkways shall be capable of supporting concentrated loads of 135 kg spaced at 800 mm, as might be applied by maintenance personnel walking on the roof. Any equipment enclosure mounted on the roof shall be capable of supporting a typical workman's toolbox weighing 12 kg.

3.4.12 Side Load

Any 2.5 m length of side sill and supporting structure shall be strong enough to resist a transverse inward load of 180 kN, evenly distributed over the 2.5 m length of side sill, without yielding or buckling. Any 2.5 m length of belt rail (at the lower side window edge) and supporting structure shall be strong enough to resist an inward transverse load of 42.5 kN, evenly distributed over the 2.5 m length of belt rail, without yielding or buckling.

3.4.13 Jacking Loads

For design purposes, the static AW0 vertical load on each jack point (symmetrical jacking) shall be increased by a factor of 4, and this load shall be combined with a horizontal load of 10% of the vertical load on each jack point applied in any horizontal direction. Under this loading condition, there shall be no permanent deformation of any carbody structure.

3.4.14 Equipment Loads

The load factor for the design of all underfloor, roof, and interior equipment, any portion of the equipment, equipment boxes, equipment hangers, standby supports, safety hangers, and the carbody supporting structure shall be 3 in the longitudinal direction, 2 in the vertical direction, and 2 in the lateral direction. The design load shall be the weight of the supported item multiplied by the appropriate load factor. These loadings shall be applied separately; each such loading may develop the ultimate load-carrying capacity of the member being investigated.

Equipment within an equipment box need not meet the above criteria provided it can be shown that the equipment will not penetrate the walls of the equipment box when exposed to these load levels. The equipment box shall conform to these load criteria with the rearranged equipment (i.e., equipment that is presumed to have broken loose) in addition to its normal arrangement.

Fastenings shall be designed so that in no case will the strength of one fastener or the shearing of fasteners through the base material be the limit of the carrying capacity of a member. All bolts used to support equipment shall be not less than 10 mm diameter.

3.4.15 Steps

Any steps shall be designed to support one person at 135 kg per 300 mm of tread with a load factor of 2. The resulting stresses in any part of the steps assembly shall not exceed the yield strength of the material.

3.4.16 Truck and Running Gear Loads

Trucks (or running gear) shall be attached to the carbody such that they shall be raised with the vehicle unless intentionally detached. Stresses in the attachment structure shall not exceed 50% of yield with the truck or running gear hanging from the body.

The structural connection of the truck (or running gear) to the carbody shall be capable of resisting a minimum horizontal force equal to three times the weight of a fully-assembled truck applied in any direction through the actual or virtual pivot without exceeding the ultimate strength of the connection, and without exceeding the ultimate strength of the carbody and truck (or running gear) support structure. This requirement for strength in the horizontal plane shall apply both with and without the weight of the carbody applied to the truck (or running gear), the latter being the case when the truck (or running gear) is hanging from the carbody when the horizontal load is applied.

3.4.17 Natural Frequency

The natural frequency of each vehicle section under a vehicle weight of AW4 and supported at the articulation yokes and at the bolsters shall not be less than 2.5 times the natural frequency of the secondary suspension.

3.5 Stress Analysis

The Contractor shall prepare and submit a stress analysis of the carbody structure and equipment supports for any equipment item weighing more than 60 kg. The stress analysis shall show the calculated stress, the allowable stress, and the margins of safety for all elements under all specified and relevant loading conditions. The stress analysis shall consist of manual calculations as appropriate supported by finite element analysis (FEA) using a computer program such as NASTRAN, ANSYS, Algor, or approved equal.

3.6 Jack Pads and Hoists

Each carbody section shall be provided with non-slip, easy to reach jacking pads at structural points to sustain jacking loads. Jacking pads shall be located considering jack placement, derailment clearances, and similar factors arising when jacking the vehicles in the shop and in the field with modern portable re-railing equipment. Jacking pad locations and their supporting structure shall permit asymmetrical jacking of any body section without cosmetic damage, deformation, or dislocation.

3.7 Floor Construction

The floor shall be constructed so that all applicable noise, vibration, strength and fire requirements in this specification are met. The floor design shall meet the fire requirements per NFPA 130 for 30 minute testing. In the event a floor construction design to another standard is proposed, the Contractor shall submit a detailed design of the proposed floor, a detailed description of the standard used, evidence of compliance to the proposed standard, and justification as to how the proposed floor design provides safety equal to that provided by compliance to NFPA 130 to passengers and the operator in the event of car fire.

3.8 Articulated Section

Articulation section shall be considered as an integral part of the carbody, including during testing as required by this specification. The articulation section shall provide stable and smooth connection between each body section under all specified operating conditions, meet all strength requirements in this section, and permit supporting the car as a whole on work stands, jacks or shop trucks.

Articulation section shall provide stable connection between carbody sections and maintain each body section up-right on level tangent track.

Articulation components which require periodical service, inspection and maintenance shall be easily accessible either from passenger compartment, side of the car, or bottom of the car at inspection pit. If the articulation section uses friction material for rotation, such material shall have adequate life over a scheduled heavy maintenance interval but not shorter than 12 months. Such material shall provide coefficient of friction as constant as possible so that the turning at curve is smooth and consistent over time without excessive flanging of the adjacent truck.

3.9 Roof Shroud

Roof shroud, if provided, shall be aesthetically consistent with the carbody styling and provide sufficient strength against the worst case combination of wind and operating speeds specified herein. The shroud shall be made of LAHT steel, aluminum or FRP with a proper weather protective finish. Shroud shall be attached to roof structure by mechanical fasteners and shall be removable by ordinary tools.

3.10 Skirts

Skirts shall be provided at the sides of the car to enclose trucks and any open spaces which may be accessible by pedestrians along the ROW. Skirts shall be made of LAHT Steel, Aluminum or FRP with proper weather protective finish and appear an integral part of the carbody. Skirts shall be attached with standard threaded fasteners. Skirts which cover equipment requiring periodic maintenance, including trucks, shall be provided with quick-release fasteners or similar devices to facilitate repeated removal and shall be provided with safety lanyards to prevent them from flying off if left unlatched. Skirts may be modified in the vicinity of trucks to accommodate turning.

3.11 Bridgeplate for Mobility Impaired Patrons

If provided, a bridgeplate shall meet the structural requirements specified in Section 6 of this document. All openings in the car floor and structure to accommodate this device shall be included in the car structure design and analyses required elsewhere in this Section. All enclosed areas shall be primed and painted as for other underfloor areas. Drainage shall be provided to prevent entrapped water at any location.

3.12 CDRL

The following design submittals are required:

Drawings and material lists showing all materials used for carbody components

3-1 If the carbody structural design is not based on EN 12663, documentation and supporting information for the proposed standard is required

3-2 Documentation and supporting information if CEM design is employed

3-3 If proposed, details of alternative method of anti-climbing design

3-4 Natural frequency data for the car structure

3-5 FEM and FEA, and supporting manual stress analysis

3-6 Demonstration of compliance with the fire test requirements of NFPA 130. If the car is designed per other standard, submit supporting documents per Section 3.7

3-7 Details of the articulation joint, indicating operation of all elements over the full operating range, service requirements and accessibility, weather sealing, and similar ranges of conditions

3-8 Details of roof shroud construction, materials, and attachment methods

3-9 Details of skirt locations, construction, materials, and attachment methods

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COUPLER

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SECTION 4

COUPLER

4.1 General

Coupling devices shall be provided to allow one vehicle to tow or push another vehicle under emergency conditions. More specific towing requirements are given in Section 2.

4.1.1 Configuration

The coupler system shall be an automatically- or manually-operated, storable, unit with resilient self-centering draft gear, presently in use on similar vehicles for the same purpose.

The coupler assembly shall be mounted to the car structure under the cab floor via bolted connection. See also Section 3.

The coupler shall be compatible with the couplers currently in use on the Seattle Streetcar – South Lake Union Line.

4.1.2 Geometry

The coupler system shall be capable of operating over track profiles specified in Section 2, including a combination of worst-case horizontal and vertical curves, superelevation, track wear, and track misalignment without damage or stress outside the system design limits. Additionally, the coupler system shall accommodate variations between adjacent cars resulting from uneven loading, wheel wear, maximum suspension travel, and suspension failure without damage or stress outside the system design limits.

4.1.3 Strength

The coupler assembly strength shall be sufficient to meet the towing requirements and operational requirements specified in Section 2.

Coupling at speeds up to 1 km/h shall be possible without damage to any coupler assembly components.

The coupler draft gear and anchor shall be capable of withstanding buff or draft loads of 400 kN with no permanent deformation. See Section 3.4.2 for coupler anchor requirements.

4.2 Draft Gear and Anchorage

The draft gear shall provide rubber cushioning for the coupler in both buff and draft, and provide resilient mounting in the vertical direction to maintain nominal coupler height above top of rail. A means of vertical height adjustment of the coupler head to compensate for vehicle and coupler variations and wear shall be provided.

The draft gear shall provide for automatic centering of the coupler. The centering device shall also allow the coupler to be manually swung to either side to facilitate maintenance and coupling on non-tangent track.

4.3 Lateral Stop

Mechanical stops shall be provided to positively limit lateral coupler swing and prevent damage to the carbody structure and other equipment in the event the vehicle is operated with the

coupler un-stowed. The stop strength shall be sufficient to withstand the impact loading of the coupler, without damage, when it is accelerated from one stop to the other, at the maximum lateral acceleration possible on the specified ROW. The stop shall be designed to fail before the structure to which it is attached.

4.4 Coupler Head

The coupler head shall provide the connecting mechanism between two couplers, and include the devices necessary to safely lock the coupler heads together when coupled.

The shape of the head shall allow for vertical and lateral misalignment between coupler heads, and provide for self-alignment with the mating coupler when the couplers are brought together during a coupling operation.

When the coupler heads mate during coupling, the coupling mechanism shall be engaged by inserting a pin, throwing a latch, or similar manual process; or, the coupler heads may latch automatically.

4.5 Storage

When not in use, the coupler shall fold or retract under the vehicle behind a removable or hinged cover.

The storage mechanism shall permit a maintainer to manually deploy and stow the coupler with minimal physical effort. A device or devices, integral to the assembly, shall be provided to lock the coupler into its operating position, and to release the coupler for storage.

In the stowed position, the coupler assembly shall be retained rigidly such that movement due to car motion is prevented.

4.6 Electrical Connections

The coupler assembly shall include a connector, wiring, and related hardware to provide a temporary electrical connection for communication between vehicles, as described in Section 13.

Connection between cars may be made by a separate cable with connectors, of sufficient length to span the distance between the coupler connectors. Alternatively, the coupler connectors, and wiring, shall be arranged to directly connect with each other. Either arrangement shall provide for all coupler motions without damage to connectors or wiring.

The connectors and wiring system shall be water-tight, and meet the multi-pin connector requirements of Section 16.20.4. A water-tight cap shall be provided to protect the connector when not in use. The cap shall be retained by chain, lanyard, or similar device when not applied.

The electrical connectors shall be compatible with the connectors currently in use on the Seattle Streetcar – South Lake Union Line.

4.7 CDRL

Design submittal requirements are as follows:

- 4-1 General arrangement drawings of all coupler components, with dimensions
- 4-2 Operating description for deploying, coupling, uncoupling, and storing
- 4-3 Detailed drawings of the draft gear, folding or storing mechanism, coupler head and latching mechanism

4-4 Material properties, coatings, lubrication requirements, and similar

4-5 Strength analysis and/or manufacturer's test data

4-6 Details of electrical connections, including connector material details

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OPERATOR'S CAB

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SECTION 5

OPERATOR'S CAB

5.1 Cab Controls

Controls and indicators necessary for vehicle operation shall be placed in the cab. Unless otherwise permitted, all controls and indicators shall be on a common console panel directly in front of the operator's seat.

All controls shall be arranged in an ergonomic manner based on the relative frequency and criticality of each task. Each control and indicator, shall have a durable and permanent label, and shall resist penetration by spilled liquids.

Controls, status indicators, and the control console materials and design shall be arranged to avoid glare on the windshield interior or to induce any other adverse visual distraction.

Controls and status indicators shall conform to IP65 standards.

At a minimum, the following components, controls and status indicators shall be integrated into each cab:

- An operator's seat (Section 14.4.2)
- A master controller (Section 5.1.1.3)
- An emergency brake mushroom switch (Section 5.4.3)
- A speedometer (Section 5.2.1)
- Radio control head(Section 13.6)
- Cab microphone and communication control panel (Section 13.3.3, 13.5.3)
- Footswitches – if provided (Section 5.4.14, 13.3.3) (
- TWC control box (Section 13.14.3.1)
- Door and bridgeplate controls (Section 6.9.2)
- A Horn and bell, and controls (Section 5.3.1)
- A windshield wiper, washer, and controls (Section 5.3.2)
- A cab air comfort system, and controls (Section 5.3.3)
- Turn signal controls and hazard flashers (Section 8.4.4)
- Headlights control (Section 5.4.3)
- Controls for turning auxiliary power on and off (Section 5.4.8)
- Controls for raising and lowering the pantograph (Section 9.2.1)
- Controls and indications for the high speed circuit breaker (Section 9.2.2)
- Controls to enter and leave wireless operating mode (Section 9.6)
- Exterior side view CCTV (Section 13.9.1)

- Status and fault indicators for all major systems (Section 17)

The functionality of these controls is described below, or in other sections within this document.

The Contractor shall submit an Operator's Cab Design Package (CDRL 5-1), for SDOT review and approval.

The Contractor shall submit a Cab Control Design Package (CDRL 5-2), for SDOT review and approval.

5.1.1 Vehicle Motion Controls

The vehicle motion control group shall consist of a Key Switch, Reverser Switch, and Master Controller. Alternative arrangements with functionality similar to that described below may be considered by SDOT.

The Contractor shall submit a Vehicle Motion Control Design Package (CDRL 5-3), for SDOT review and approval.

5.1.1.1 Key Switch

A Key Switch shall be provided to select the cab status. The Key Switch shall be mechanically interlocked with the Master Controller and Reverser Switch, such that in the:

- ON Position
    - Cab controls and all other vehicle systems shall be activated and functional.
    - The cab console in the other end of the vehicle shall be disabled.
    - The key shall not be removable in this position.
- OFF Position
    - All cab controls shall be non-functional, except the Emergency Brake pushbutton.
    - The key shall be removable in this switch position.
    - When both cabs are OFF
        - All cab controls and vehicle systems shall be inactive and powered down, except for those systems that are maintained by the hotel load timer, or those systems specified to be active at all times.

Additional Key Switch and Cab Interlock controls are detailed within this Section.

5.1.1.2 Reverser Switch

A three position, (FORWARD, NEUTRAL, REVERSE), Reverser Switch shall be provided.

The Key Switch and the Reverser Switch shall be mechanically interlocked so that the Reverser Switch cannot be moved from the NEUTRAL position unless the associated Key Switch is in the ON position, and the Key Switch cannot be moved from the ON position unless the Reverser Switch is in the NEUTRAL position.

The vehicle control circuitry shall be such that vehicle operation shall not be possible unless the Reverser Switch in the controlling cab is placed in either the FORWARD or REVERSE position.

The Reverser Switch shall be interlocked such that the Master Controller handle must be in the MSB position in order to move the Reverser Switch out of either the FORWARD or REVERSE position.

Activation of more than one Reverser Switch at the same time shall initiate an MSB application.

5.1.1.3 Master Controller

A Master Controller (MC) shall be provided to allow manual selection of braking and motoring efforts. The MC shall be arranged to move linearly fore and aft, with motoring in the forward direction and braking towards the rear (that is, towards the operator).

There shall be distinct tactile positions in the handle travel, indicated by stops or detents, as indicated below:

- Maximum Brake (MB) Stop (rearmost position)
- Maximum Service Brake (MSB) Detent
- Minimum Brake Detent
- Coast Detent
- Minimum Power Detent
- Maximum Power Stop (forward most position)

Maximum Brake (MB) is defined in Section 2.5.5. Maximum Brake is considered a safety system. The circuit shall be a safe function as defined in Section 2.10.

Between Maximum Power and Maximum Service Braking, braking and power efforts shall be linearly proportional to handle position.

The MC shall stow in the MSB position when the cab is inactive. The MC shall be mechanically interlocked such that it may be moved from the MSB position only when the Key Switch is in the ON position, and the Reverser Switch is in either the FORWARD or REVERSE position.

The handle shall be shaped, located, and oriented so as to minimize strain and fatigue on the operator.

5.1.1.4 Deadman

The Master Controller handle shall incorporate a deadman protection circuit. Release of the handle shall cause the deadman circuit to initiate an MSB application after a two second time delay. The circuit and timing function shall be a safe function as defined in Section 2.10.

After initiation by the deadman circuit, the brake application shall be retrievable by the operator by cycling the MC to MSB.

The deadman function shall be disabled when the controller handle is in the MSB or MB positions.

5.1.2 Door Controls

Controls for passenger doors and bridgeplates shall be positioned for safe actuation and convenient operation, with the right side door controls on the right side of the console, and the left side door controls on the left side of the console. Refer to Section 6 for a description and function of the required controls.

5.1.3 Hotel Load Timer

A user-programmable timer shall be provided, which shall keep the HVAC, interior lights, exterior lights, and passenger door control, active after both cabs are switched to OFF. These systems shall shut down at the end of the timer setting. The timer shall be initially set to 20 minutes and shall be adjustable from 1 to 30 minutes in 1 minute increments. The timer shall have an OFF position which allows the vehicle to remain powered up indefinitely for maintenance activities. The timer shall be easily accessible by maintenance personnel or as an option a separate by-pass switch shall be provided in the cab.

5.2 Cab Indicators

Indicators, visual and audible, of approved types shall convey all information relevant to safe and efficient vehicle operation.

Health and status of all vehicle systems shall be displayed on an industrial-grade LCD panel, via the vehicle's data network. Refer to Section 17.5 for specific monitoring and diagnostic system requirements.

There are some indications that shall be continuously displayed. At a minimum, these shall include, a speedometer, door closed indication, brake released indication, wireless operation and cut-out activation indication.

The operator's console shall also include indicator lights for critical status and other functions, as approved.

5.2.1 Speedometer

An analog speedometer shall be provided. The speedometer shall display speed from a dedicated speed sensor, or a speed processed by one of the vehicle systems. In either case, the speed signal shall be compensated for actual wheel diameter.

The display shall be 125 mm in diameter, minimum. The indicated range shall be 0 to 50 mph, and shall span approximately 270 degrees of the face. The speedometer shall be evenly illuminated over the entire display, with a dimmer control. Indicator and face colors shall be selected for maximum visibility, as approved.

5.2.2 Odometer

The propulsion system shall provide distance information to the MDS system that will display the odometer mileage for the vehicle on the cab display.

An alternative source for the distance information to the odometer may be presented during design review.

5.3 Miscellaneous Cab Equipment

5.3.1 Warning Devices

Warning devices are required for operation on city streets and where intermixed with pedestrians.

The automobile warning device shall be a multiple tone horn mounted at each vehicle end. Activation shall be by a momentary switch in the adjacent cab. The horn shall have an audible output of at least 95 dBA at 30 m in front of the vehicle.

A traditional sounding trolley bell shall be provided for pedestrian warnings. The bell shall have two volume settings, low and high, with a high setting minimal sound pressure level of at least 75 dBA, measured at a distance of 30 m. Activation shall be by a momentary switch in the adjacent cab on the operator's hand hold. Sound level shall be selected by a console mounted selector switch. The bell shall produce a repeating sound with a repetition rate of approximately two strikes per second in response to continuous switch activation.

Warning sounds, horn and bell, may be produced by amplified, digitally-sampled audio data, heavy duty weatherproof speakers on each end of the vehicle shall be the source for the warning sounds. The volume of the warnings shall be adjustable by the maintenance personnel.

The Contractor shall submit warning device sounds to SDOT (CDRL 5-4) for review and approval.

5.3.2 Windshield Wiper and Washer

A windshield wiper (or wipers) shall be provided for each cab windshield. At least 80% of the width and 60% of the height of the total windshield area shall be swept over one complete cycle. Windshield wiper controls shall provide for variable speed and for interval operation to suit a wide range of rainfall conditions. Windshield wipers shall automatically park at a secure and unobtrusive location when not active.

Windshield wipers shall be provided with fluid dispensing windshield washers to aid in maintaining clear operator vision. The washer nozzle shall be attached to each wiper blade, and move with the blade. The washer fluid reservoir shall be easily accessed for refilling.

The Contractor shall submit a Windshield wiper and washer system Design Package to SDOT (CDRL 5-5) for review and approval.

5.3.3 Air Comfort System

Each cab shall be provided with heating and cooling air flow controlled by operator adjustable louvers in the cab air grille. Cab windshield and side window defrosting and demisting shall also be provided. Capacity and control parameters are described in Section 7.

5.3.4 Operator's Seat

See Section 14.4.2.

5.3.5 Sunscreens

Adjustable sunscreens shall be provided as need to aid the operator in all external light conditions, including simultaneous front and side sunlight. Each screen and its: material, mounting, and adjustment, shall be service-proven in a similar transit application; considering factors, window size/arrangement, operator position, color, and light blockage ratio. The sunscreen material shall not neutralize the color of traffic control signals.

5.3.6 Interior Mirror

One or more interior mirrors shall be provided in the cab. The mirrors shall be located and adjustable to provide the operator with a view of the passenger compartment. The mirror shall be of distortion free glass installed in an edge covering frame. The mirror reflecting area shall be at least 360 cm^2.

5.3.7 Exterior Side View Screen

The flat exterior side view video screens described in Section 13.9.1 shall be mounted on the right and left sides of the console or corner posts. They shall be arranged to be viewed easily by seated and standing operators.

5.3.8 Fire Extinguisher

A 4.5 kg capacity fire extinguisher with a minimum rating of 4-A:30-B:C, marine type, shall be located in each operator's cab. The fire extinguisher shall be listed by Underwriters Laboratory and shall be provided with a marine type mounting bracket.

The fire extinguisher shall be clearly marked and accessible to the operator.

5.3.9 Other Cab Equipment

Two (2) duplex convenience outlets, rated for 120 Vac, 20 A service , shall be provided, one in each cab, at locations approved by SDOT. Each ground fault circuit interruption (GFCI) protected outlet shall be fed from a dedicated circuit breaker.

A mount for the switch iron and pantograph crank shall be provided in the A end operator’s cab, as approved by SDOT (Include in CDRL 5-1).

5.3.10 Operator’s Hand Hold

A horizontal hand hold for the operator’s right hand shall be provided on the front edge of the console shelf. The hand hold shall include a thumb-operated switch to activate the warning bell and the push-to-talk (PTT) switch for the communication system, location to be approved by SDOT.

5.4 Control Configurations and Interlocks

Various vehicle control schemes shall be implemented as described below. Control of systems not described below shall be determined by the Contractor.

Unless otherwise indicated or approved, all control signals, interlocks, and other vehicle level controls shall operate from the vehicle battery supply, or as approved by SDOT.

The Contractor shall submit a Control Configuration and Interlocks design package (include in CDRL 5-2), for SDOT review and Approval.

5.4.1 Cab Interlock

Control lines and associated circuitry shall be used to interlock the cab controls such that no more than one cab can take control of a vehicle at the same time.

All interlocking shall be provided by relay logic. Interlocking that depends on mechanical locking of transfer switches with electrical solenoids is prohibited.

5.4.2 Direction Control

Direction signals shall be given by a pair of control lines, designated Forward and Reverse relative to the A end of the vehicle. The associated circuitry shall be arranged such that one control line must be energized while the other must be de-energized for correct operation. Energization or de-energization of both control lines at the same time shall inhibit propulsion.

Direction signals shall originate at the controlling cab's Reverser Switch.

5.4.3 Emergency Brake

Operator control of emergency braking shall be provided by an Emergency Brake Switch mounted on the operator's console in each cab.

The console Emergency Brake Switch shall be a heavy duty, industrial grade pushbutton gang switch with a large, red mushroom-shaped actuating head. The switch mechanism shall be arranged with two switches for the main emergency brake circuits, with a switch in each of the positive and negative portions of the circuits. The actuation mechanism shall be sufficiently robust such that striking the mushroom head will assure breaking the circuit even with welded contacts.

When an EB is commanded spin/slide control shall be disabled.

The emergency brake circuit shall be interlocked with the no-motion detection system such that, once emergency brake is commanded, the emergency brake circuit cannot be reset to the normal state until no-motion is indicated.

The active cab shall provide the only power and return circuits for control of all emergency brake equipment in the vehicle. These circuits shall be controlled in a double break manner such that both the positive and negative supply leads to the emergency brake relay are switched by the console Emergency Brake Switch, the cab control and interlock relays.

The emergency brake control circuits shall be treated as vital, with maximum isolation maintained from possible sources of false energization.

All emergency brake circuits shall be arranged in a fail safe manner, requiring that control lines be energized to sustain a permissive condition.

5.4.4 Track Brake Control

Track brakes shall be controlled via a control line that is energized to apply the track brakes. All track brakes in a vehicle shall be applied when commanded either by a brake application or manually via the console track brake switch.

When commanded by MB or EB, track brakes shall be interlocked with the no-motion system such that track brake application is canceled below the no-motion detection point.

Manual operation of the track brakes via the console switch shall not be canceled below the no-motion detection point. Propulsion shall not be inhibited by a manual track brake application.

Any track brake application shall activate the brake lights at the rear of the vehicle.

5.4.5 Passenger Stop Request

Activating the passenger stop request anywhere in the vehicle shall sound the local stop request chime only in the passenger area of the vehicle, and shall sound an audible alert for 0.5 seconds in the operator’s cab, as approved by SDOT. The stop request shall illuminate a light on the operator’s console.

Once activated, the cab stop request light shall remain illuminated and the cab audible alert shall latch off, until the doors have been cycled.

5.4.6 Bridgeplate Deploy

Pressing the passenger bridgeplate deploy request button anywhere in the vehicle shall sound the local stop request chime in the passenger area of the vehicle, and shall sound a unique

audible alert for 0.5 seconds, and illuminate a bridgeplate deploy request light in the operating cab.

Once activated, the cab bridgeplate deploy request light shall remain illuminated, and the cab audible alert latched off, until the bridgeplates have been cycled. See Section 6 for door and bridgeplate controls.

5.4.7 HVAC Control

The HVAC system shall be activated automatically whenever a Key Switch in either cab is placed in the ON position. The HVAC system shall remain active when both cabs are OFF until the hotel load timer expires.

5.4.8 Auxiliary Power Control

The ac inverter and LVPS shall be activated automatically whenever a Key Switch in either cab is placed in the ON position, and shall shut down after the hotel load timer expires when both cabs are OFF.

The battery charger, or battery charger portion of the LVPS, shall remain operational whenever the pantograph is raised and there is line voltage present.

Each cab shall have an Auxiliary On/Off switch, which shall turn On or Off the auxiliary loads. The Auxiliary On/Off switch shall not be functional if a Key Switch is activated in any Cab.

5.4.9 Exterior Lighting Control

Marker lights at both ends of the vehicle shall be illuminated red whenever there is an active cab. When a direction is selected with the Reverser Switch, the marker lights shall be illuminated, red at the rear of the vehicle and amber at the front of the vehicle.

Taillights shall be illuminated at the rear of the vehicle whenever a direction has been selected. When the auxiliaries are on and no direction is selected, the taillights shall be illuminated at both ends of the vehicle.

Stop lights shall be illuminated at the rear of the vehicle whenever the auxiliaries are on, a direction has been selected and the vehicle is in a braking mode. For this purpose, braking mode shall be considered as the application of dynamic, friction, or track brakes.

5.4.10 Interior Lighting Control

Lighting in the passenger compartment shall be on whenever either cab is ON, and shall remain active with both cabs OFF until the hotel load timer expires or the auxiliaries are turned OFF.

5.4.11 Door Control

Door control shall be as described in Section 6.

5.4.12 Parking Brake Control

The parking brake shall automatically be applied when both reversers in each cab of the vehicle are in the Off position, or both key switches are in the Off position.

5.4.13 Bypass Circuitry

The following sealed switches shall be provided. The seal shall be breakable without the need for tools by the operator. The bypass active indicator shall illuminate if any bypass switch except Audible Alert Bypass is thrown.

- Audible Alert Bypass: Acknowledges and cancels the following audible alarms:
    - Emergency door operating device activated
    - Friction brake or dynamic brake fault
    - The use of this switch shall not affect illuminated indicators associated with these alarms and its use shall not illuminate the Bypass Active light.
- No-Motion Bypass: This switch shall bypass the local no-motion detection circuits which prevent door operation.
- Door Interlock Bypass: This switch shall bypass the summary door interlock circuit which prevents propulsion in the event of an open door or deployed bridgeplate.
- Speed Restriction Bypass: Deactivates the circuit which limits or restricts vehicle speed due to dynamic brake failure.

The bypass switches shall be in the circuit only if the operator's console is activated in the same cab as the bypass switches. When the console key is turned to OFF, all units shall automatically return to normal function and remain so when that cab's console is re-activated.

5.4.14 Sander Control

A switch shall be provided for the operation of the sander system. The switch shall be a footswitch or console-mounted switch, as chosen by SDOT. The switch shall be of the momentary, spring-loaded type, arranged such that sand is applied to the rails in front of the leading wheels of a truck.

Manual operation of the sanders via the switch shall not be canceled below the no-motion detection point. Automatic operation of the sanders via master controller or emergency brake application shall be canceled below the no-motion detection point.

5.5 CDRL

The following submittals are required:

5-1 Operator's Cab Design Package, depicting all features required in Section 5.

a. General arrangement drawings of the cab, including:

i. Plan, profile, and front elevation drawings of the interior, showing all visible features, with dimensions

ii. Plan and elevation views of cab console, including operator's seat, side windows, all console controls and displays

iii. Drawings showing seated operator's range of visibility out the windshield, and views through the mirrors

iv. Foot switch location

v. Drawings of all control, indicator, and breaker panels, with all components identified

b. Parts List

5-2 Cab Control Design Package

a. Functional description of all cab controls

b. Control schematics
c. Software design description
d. Software flow diagrams
e. Functional description of the vehicle status monitor, including:
    i. Sample screen displays, monitor details (resolution, colors, etc).
    ii. Listing of available displayed data for each system

5-3 Vehicle Motion Control Design Package

5-4 Warning Devices sounds (electronic audio files)

5-5 Windshield Wiper and Washer System Design Package

SECTION 6

PASSENGER DOORS

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SECTION 6

PASSENGER DOORS

6.1 General

All doors shall be of the sliding or sliding plug type. Each doorway shall include two door panels which slide in opposite directions, parallel to the side of the car. The doors shall be flush with the car body exterior skin when closed. Doors shall not protrude more than 75 mm from the vehicle side during any portion of the open or close cycle.

Bridgeplates shall be provided to meet ADA requirements, 49 CFR 38.83.

All door and bridgeplate equipment shall be interchangeable from one location to any other location and from car to car. To this extent, all mounting holes for all hardware shall be jig-drilled to insure interchangeability.

All doors shall be vibration and rattle free, while the vehicle is underway, and while doors are operating when the vehicle is stationary. The door system, in conjunction with the vehicle's aerodynamics, shall prevent whistling and other objectionable noises at all vehicle speeds.

The door and bridgeplate system shall be designed in accordance with the safety requirements of Section 2.10. No single point failure of the door and/or bridgeplate system shall cause:

1. Any door or bridgeplate to unlock and/or open when an open request has not been commanded
2. A door or bridgeplate open command to be transmitted or responded to when the train is in motion
3. A door or bridgeplate closed indication to be transmitted when any door or bridgeplate is unlocked or open
4. A traction interlock OK status when any door or bridgeplate is unlocked or opened
5. A door or bridgeplate closed indication to be transmitted when an unlock or opening command is stored anywhere in the system

The Contractor shall submit for SDOT review and approval,

- Door System design package (CDRL 6-1)
- Bridgeplate System design package (CDRL 6-2)
- Door and Bridgeplate Controller and System design package (CDRL 6-3)
- Door and Bridgeplate systems integration package (CDRL 6-4)

6.2 Door Panels

6.2.1 General Requirements

All side doors shall be of LAHT steel or aluminum construction, and joined into an integral unit by adhesive bonding or resistance welding. All edges and joints shall be completely sealed to prevent the infiltration of moisture. Interior cavities, where it is possible for condensation to form, shall be provided with drain holes at the bottom.

Each door panel shall contain a laminated safety glass window, of the same materials and color as the side windows. The window height shall be sufficient to permit direct viewing of the door closing and bridgeplate movement warning signal by a passenger on the platform, when the doors are closed.

Door windows shall be retained in the door panel by the same method used for passenger windows. The window retention arrangement shall be watertight.

6.2.2 Strength Requirements

The door panel skin, structure, and mounting hardware shall sustain a concentrated load of 890 N applied perpendicularly to the plane of the door at any location on the panel, with the door panel installed on the car; the load-bearing surface shall be 100 mm by 100 mm for this requirement. The allowable maximum deflection under these conditions with the door simply supported at the top and bottom shall be limited to 10 mm maximum with no permanent deformation after the force is removed.

6.2.3 Weather Sealing Requirements

The door panels and doorways shall be weather-stripped to be watertight when the car is being washed and for all service speeds with the worst case possible combination of climatic conditions as described in Section 2.2.4. The doors shall provide sufficient sealing to maintain required HVAC pressurization.

Sealing shall be provided by a vertical seal at the car body edges, the top edge of the door, the forward edge of the door where the panels meet in the closed position, and at the bottom edge. All seals shall be applied in a manner which enables them to be easily replaced with the door panels in place.

6.3 Door Operator

Door movement shall be via electrical operator and shall have sufficient power to reliably open and close the doors at the specified performance levels with the most unfavorable ambient wind and vehicle pressurization conditions. The left and right door panels in a given doorway shall move simultaneously. One operator shall be provided per doorway.

The connection between the door operator and door panels shall be mechanical via screw shaft, linkages, or toothed belts. Fluid or pneumatic devices are not permitted.

The operator shall be located in the transom area above the doorway. All operator equipment shall be concealed, except as necessary 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 on the operator assemblies, and to remove the assemblies as complete units.

All door tracks shall be mounted within the carbody or within the door panel. Separate sliding door lock assemblies, if required by the door design, shall be within the carbody.

The operator shall be powered from the low voltage dc power system and shall be capable of operating over the specified voltage range without affecting the reliability, specified performance, or service life of the operator. The operator shall be capable of withstanding stall current indefinitely, or, alternately, shall be capable of detecting this condition and removing

power if it persists for a preset time, without adverse affect on the reliability and service life of the equipment.

6.4 Door Operator and Bridgeplate Controller

6.4.1 Door Controller

Each door operator shall be controlled by a microprocessor-based control module located either immediately adjacent to, or in, the door operator compartment. The door controller shall meet all requirements of Section 17.

The system shall control all aspects of door motion, including opening speed, closing speed, closing forces, detection of stalls, accelerations and decelerations, and door close time delays.

The controller shall monitor commands from the cab console and local passenger switches, no-motion status, door obstructions, and provide system diagnostics (see below).

The system shall monitor door position continuously from fully opened to fully closed as part of its control function. All position sensing shall be via non-contact proximity-type sensors not requiring adjustment. This position sensing is in addition to the interlock requirements below.

6.4.1.1 Diagnostics and Adjustments

The status of the door system shall be available via a diagnostics system integral to the door controller software. The diagnostic system shall monitor all critical internal functions, external inputs, and the mechanical door system, 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 vehicle's data network. Status and diagnostic information from each door shall be available at a single common location, and on the operator's console; see Section 17 for additional requirements.

Failure of the network links shall have no effect on door operation, and network failures shall be announced at the diagnostics port, and operator's console.

Diagnostics from each door controller shall also be available either via separate connector at the controller, or via 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.

The mounting of all sensors and switches shall be such that no readjustment is possible when any given switch is replaced. There shall be a separate adjustment location for system wear.

The Contractor shall submit the Door Diagnostics and Adjustments (CDRL 6-5) to SDOT for review and approval.

6.4.2 Bridgeplate Controller

Each bridgeplate shall be controlled by a microprocessor-based controller similar in functionality to the door controllers, above, and shall meet all the requirements of Section 17. Bridgeplate control may be integrated into the door controller. The bridgeplate controller shall be linked to the vehicle data network.

The Contractor shall submit the Bridgeplate Diagnostics and Adjustments to SDOT for review and approval (include in CDRL 6-5).

6.5 Door Control Panel

An independent door control panel shall be provided for each doorway to provide interfaces with the vehicle, to control door operations, and to provide access for monitoring door performance and function. The door control panel may also provide control for the bridgeplate at that doorway. The control panel shall use microprocessor-based logic and shall provide user-access to control parameters and status of the doorway via laptop computer.

The door control panels in the vehicle may communicate with each other, but the interfaces with the vehicle door and bridgeplate commands and no-motion interlocks shall be on a per-doorway basis.

The control panel shall include provisions for adjusting and controlling door opening and closing speeds, door closing forces, bridgeplate deploy forces, and bridgeplate deploy and retract speed, door timing, and similar features via laptop computer and software provided by the door supplier.

The control panel shall be located in the transom header area adjacent to the door operator.

6.6 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.

6.6.1 Door Operation

Doors may be opened by the operator, or by passengers on the inside or outside of the vehicle. A front door on each side shall also be controlled by exterior crew switches.

Door (and bridgeplate) operation shall only be possible when a cab key switch is ON (except for crew switches), the vehicle has achieved no-motion, and the Master Controller is in the MSB position.

All door operations shall be enabled by the operator via a Release command issued from the operator's console. The Release command shall be interlocked with the no-motion circuitry both in the cab and at each doorway.

Issuing a Release command for the doors on a given side of the vehicle shall cause the local door control panels to enable and illuminate the inside and outside passenger door pushbuttons on that side of the vehicle, indicating to passengers that door control is available. Pressing a pushbutton shall cause the enabled door to open. The door shall stay open for a pre-set time, then automatically close. This time shall initially be set to 10 seconds, but SDOT shall have the ability to set this to any value between 0 and 60 seconds, and infinite time such that the doors remain open till commanded closed.

The operator may open all doors on a vehicle side by issuing an Open command from the console. An Open command from the console shall automatically cause a Release command to be issued. The Open command shall be interlocked with the no-motion circuitry both in the cab, and at each doorway, independently of the Release command.

The Open and Release commands must both be present at each doorway before any given door can open.

When a door is open, the associated passenger pushbuttons shall be disabled and go dark.

If opened by an Open command by the operator, all open doors shall remain open until the operator issues a Close command from the console, at which time all Release and Open commands for the selected side shall be canceled and all doors on the selected side of the car shall close.

The bridgeplate, and its associated doorway, have related control functions and interlocks.

6.6.2 Door Locks

The doors shall be positively retained in the closed position via mechanical means. The lock function may be a separate mechanical lock or an over-center function of the operating linkage if the linkage is directly connected to the door panels. If the operator employs a drive belt, the lock mechanism shall not rely on the belt. The lock shall automatically engage when both door panels reach the closed position, and shall not require electrical power to remain locked.

6.6.3 Performance

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 0.15 seconds if the associated bridgeplate is not deployed. If the associated bridgeplate is deployed, the first motion of a door panel shall not exceed 0.15 seconds after the bridgeplate is fully deployed.

The operating time of any door, from time of first motion to the point of completion, including cushioning, shall be 3.0 seconds to open and 4.0 seconds to close, $\pm$0.5 seconds. The maximum door closing speed shall be 400 mm/s. Operating times shall be adjustable by SDOT via PTU or laptop computer.

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.

The design and methods for door obstruction shall be submitted to SDOT for review and approval (CDRL 6-6)

6.7.1 Operational Requirements

An electrical 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. This timing circuit shall be adjustable in software from zero to 10 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, 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

Each obstruction detection system, electrical sensitive edge and additional approved method, 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 Bridgeplates

An electrically powered bridgeplate shall be provided to bridge the gap between the doorway threshold and the wayside low platform on each side of the vehicle, to assist in the boarding of wheelchair passengers. The ramp design shall meet 49CFR Part 38-83 (c), except that the bridgeplate width shall be no less than the width of the fully open doorway. The referenced bridgeplate side barriers are required. The referenced 50% load requirement shall be interpreted as AW2 loading.

6.8.1 Bridgeplate Operation

The bridgeplate shall be deployed via operator request or in response to passenger request.

The door Release command, in addition to its door functions, shall also enable the bridgeplate controls at the respective door, and the local controller shall illuminate and enable the bridgeplate pushbuttons and tape switches.

A separate Bridgeplate command shall be available to the operator on the console. If a door Release command has not previously been issued, a Bridgeplate command given by the operator shall issue a Release command. All doors on the respective side shall become released and the bridgeplate shall deploy. A user-selectable option shall be available in the control system that allows an Open command to also be issued whenever the Bridgeplate command is given by the operator, thereby opening the door with the bridgeplate automatically after the bridgeplate is deployed.

If the Release command is already active, pressing the Bridgeplate command at the local door will deploy the bridgeplate, and open the door once the bridgeplate has deployed.

If a door is open when a valid Bridgeplate request is given (either from the operator or local pushbutton), the door shall automatically close, the bridgeplate shall deploy, then the door shall re-open when the bridgeplate is fully deployed.

If a passenger issues a Bridgeplate request via local pushbuttons before the train stops, the bridgeplate for that door shall automatically deploy before the door opens, once the doors have been released by the operator, regardless of the origin of the Open command.

The bridgeplate shall remain deployed until the operator issues a door Close command, at which time the bridgeplate shall retract after the associated door has closed and locked.

In the event of a loss of local control power, the bridgeplate shall remain in the last commanded position during the absence of control power and when power is restored.

6.8.2 Bridgeplate Interlocks and Locks

The bridgeplate shall be interlocked with the local door controls and the no-motion circuitry, such that the bridgeplate can only deploy or retract when the door is closed and locked.

If the bridgeplate has been commanded to deploy, the associated door shall not open until the bridgeplate is fully extended.

The bridgeplate mechanism shall include a positive locking feature which automatically engages when in the retracted position. A switch shall be provided to sense the status of the locking device.

A second switch shall be provided to directly sense the fully retracted position of the bridgeplate.

The two switches shall be electrically in series in the Door Status Interlock loop circuit described in this section such that the summary door status relay shall not pick up if any bridgeplate is not fully retracted and locked. The mounting of the sensing switches, and design of the mechanisms, shall be such that no readjustment shall be necessary when any given switch is replaced.

6.8.3 Bridgeplate Construction

The bridgeplate and its mechanisms shall be located beneath the side door threshold. The bridgeplate shall deploy horizontally outward and then tilt downward to meet and rest on the platform surface. The bridgeplate mechanism shall have sufficient vertical range of motion to rest on the platform surface by gravity alone under all specified conditions.

All the structural components of the bridgeplate shall be constructed of aluminum or stainless steel. If guide rollers are used, they shall be stainless steel with permanently lubricated bearings. Other rolling and sliding surfaces shall be designed not to require periodic lubrication.

The doorway threshold shall include a hinged portion that extends with the bridgeplate, such that the bridgeplate and doorway threshold form a continuous ramped surface. The slope of this surface shall not exceed ADA requirements, referenced above, under the following conditions:

- Minimum platform height
- New wheels
- Maximum floor height of car loaded to 50% of AW2 passenger load

The bridgeplate ramp shall not extend more than 490 mm beyond the edge of the threshold when fully extended. The bridgeplate shall function correctly at the maximum platform height with all car weights of AW0 to AW3, wheel wear of up to 10 mm radius unless compensated.

The ramp portion of the bridgeplate and the threshold shall be constructed of cast aluminum or stainless steel. A non-skid surface shall be applied to the bridgeplate ramp. Adhesive backed, non-skid "tape" or sheets are not permitted.

The bridgeplate shall span the full useable width of the door opening, and be capable of filling the vertical and horizontal gaps encountered at station platforms.

The ramp shall support a load per 49 CFR 38.83 (c) (1).

Edge treatment shall consist of beveling ramp and threshold edges. Such edges shall not be greater than 13 mm nor less than 3 mm thickness and shall be rounded to eliminate sharp edges.

When being deployed or retracted, the force capable of being exerted by the bridgeplate on a wayside obstruction shall be adjustable from 130 N to 400 N. When an obstruction is encountered the bridgeplate mechanism shall stall until the obstruction is removed. The mechanism shall be capable of maintaining such a stall condition indefinitely without damage or reduction in the life of any component.

Provision shall be made for manual operation of the bridgeplate mechanism such that the bridgeplate may be manually deployed or retracted in the event of power failure. The bridgeplate interlocks shall not be defeated by manual operation. The mechanism for manual operation shall not be readily accessible to passengers.

A replaceable wear strip shall be provided at or beneath the outboard edge of the bridgeplate ramp, where it contacts the wayside platform.

6.9 Control Switches and Pushbuttons

6.9.1 General Requirements

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 in the SDOT rail transit environment. All switches shall be rated per IP65.

6.9.2 Cab Console Switches

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

The switches for each side shall be: Open, Release, Close, and Bridgeplate.

6.9.3 Crew Switches

One door at each end of the vehicle 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 shall have three positions, with spring-return to center: Open, Neutral, Close. When the crew switch is rotated to the Open position, the adjacent door shall open.

When the switch is rotated to the Closed position, the door shall close. The control logic shall be configured to allow closing of any door that has been opened from the crew switch from an active cab console.

The crew switch and associated circuits shall be considered a safety circuit, and shall meet the requirements of Section 2.10.

6.9.4 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.

Each ADA accessible door opening shall also be provided with illuminated passenger bridgeplate pushbuttons and tape switches on both the inside and outside of the vehicle, a total of three per doorway, for passenger bridgeplate operation.

The interior door and bridgeplate pushbuttons shall also provide the passenger stop request function. See Section 5.4.5.

The door and bridgeplate pushbuttons and surrounding bezels, and the bridgeplate tape switches, shall be color-coded with approved colors. The tape switch shall be mounted over a colored band at least 25 mm in width to improve visibility.

The switch names shall be molded into the switch in raised lettering, dimensioned to permit sensing by a visually impaired person. The International Symbol of Accessibility (wheelchair) shall be applied to the bridgeplate switches, if large enough, or on the car adjacent to the switches, if the switch area is insufficient for good visibility.

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 and tape switches shall be approved by SDOT.

6.10 Manual Door Release Mechanism

Interior and exterior door release mechanisms shall be provided to permit doors to be opened locally without the use of electrical power. Operation of the release mechanism shall also initiate an irretrievable Full Service Brake stop. A reset device shall be provided to restore the doors to their normal operating condition after use of a manual release mechanism. The reset device shall be contained within the door control panel or transom area above the doors. Access to this area shall be by the crew key.

6.10.1 Interior Manual Door Release (Passenger Emergency Switch)

A lever or pull knob to operate the combination manual door release mechanism and passenger emergency switch (release device) shall be provided on the interior of the car at each doorway in a location accessible to all passengers. This release device is to be used under emergency conditions only, and suitable measures shall be taken to assure that its location and enclosure discourage everyday use. Suitable graphics shall be provided to explain operation in an emergency and warn against unlawful use. The graphics shall advise that the emergency door opening device is also an emergency stop activating device.

Activation of this release device shall allow both panels in a doorway to be unlocked and manually pushed open regardless of whether electrical power is available or not. This mechanism shall override all other door controls and devices. When the manual release mechanism is activated, the following shall automatically occur:

- The motion of the release knob or lever shall cause the release mechanism to interrupt the door status interlock causing propulsion power to be removed and a MSB brake application to be applied. Circuitry shall be provided to annunciate "PASSENGER EMERGENCY" on the console indicator panel in each cab and sound a cab audible alert.
- The motion of the release knob or lever shall then cause the mechanism to unlock the adjacent door panels and open them approximately 25 mm to allow the door panels to be manually pushed fully open. Electrical power to the door operator shall be removed from the door operator.

Operation of the release mechanism shall not electrically bypass the no-motion interlock.

6.10.2 Exterior Manual Door Release

Key operated manual door release devices shall be provided for crew, maintenance and emergency personnel use for entry to the car when no power is available. Two releases shall be provided, each diagonally opposite the other at the side doors. Use of this feature shall require the crew key.

6.11 Interlock Requirements

6.11.1 No Motion Interlock

All door and bridgeplate controls shall be electrically interlocked, in a failsafe and redundant manner (Section 2.10), with the no-motion trainline, described in section 2.5.10, so that the doors and bridgeplates can be: powered, opened or released, only when the vehicle has reached no-motion. When motion is detected, a close command shall be issued to all doors and bridgeplates in the vehicle, the doors and bridgeplates shall not respond to any open or release commands until no-motion is detected.

Power to the door and bridgeplate opening (deploy) circuits, the operators motor, shall be switched with non-welding critical circuit relays, as approved by SDOT, 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.

Independent of these interlocks, the door control logic shall monitor the no-motion trainline and ignore any open or deploy commands without a no-motion signal present, and shall issue a fault indication if this condition occurs.

6.11.2 Door Status (Open) Interlock

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

For each side of the vehicle, the switches shall be placed in series, activating a Summary Door Status non-welding critical circuit relay, as approved by SDOT, when all door panels are properly closed and locked. If any one of the closed or locked switches is not made up, the Summary Door Status relay shall not be energized, the cab Door Open light for that side of the vehicle shall be illuminated, propulsion power removed, and Maximum Service Brake (MSB) 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 MSB 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 door or bridgeplate 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.

The mounting of all sensing switches shall be such that no readjustment shall be necessary when any given switch is replaced.

6.12 Bypass Devices

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

6.12.1 Door Interlock Bypass

A sealed door interlock bypass feature shall be provided in each cab. This function shall be active only when the associated operator's console is powered. It shall permit movement of the vehicle under emergency conditions in the event that all doors and bridgeplates are not sensed as being closed or retracted and locked, and the source of the difficulty cannot be readily determined.

The door interlock bypass feature 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.

6.12.2 Door Cutout

A 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 cut out:

- Disconnect door motor and door controller.
- Bypass door-closed and door-locked interlocks for that door.
- Assure that the door remains closed by mechanical restraint; however, operation of the manual door release devices shall disable or release this mechanical restraint to allow the door to be opened.
- Deactivate the local passenger pushbutton lights and annunciate a cutout in the operator’s cab.

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

6.12.3 Bridgeplate Cutout

A bridgeplate cutout feature shall be provided at each bridgeplate and shall be arranged to perform the following functions in the event of a defective bridgeplate:

- Manually retract the bridgeplate via hand crank or other hand tool. This shall not require disassembly of any bridgeplate mechanisms.
- Bypass retracted and locked interlocks for that bridgeplate.
- Assure that the bridgeplate remains retracted by mechanical restraint.
- Deactivate the local passenger bridgeplate pushbutton lights and annunciate a cutout in the operator’s cab.

All tools and related cutout devices shall be in a convenient location adjacent to the affected doorway or in the transom area above the doorway.

6.13 Annunciators

The Contractor shall submit a Door and Bridgeplate Warning Indication (CDRL 6-7) for review and approval by SDOT.

6.13.1 Door Open Indications

Two Door Open indicator status lights shall be provided on the cab console indicator panel, one for each side of the car. The indicators shall be illuminated when any door or bridgeplate on the associated side of the vehicle is sensed as being unlocked, open (or deployed), or both.

6.13.2 Door Warning Announcements

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 alarm, 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 SDOT.

An Amber door closing and bridgeplate movement visual warning 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 vehicle regardless of door position. If the visual door warning cannot be seen from outside the vehicle 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 SDOT.

6.13.3 Bridgeplate Deploy Request Indication

A Bridgeplate Deploy Request indicator light shall be provided on the operator's console indicator panel. The indicator shall be illuminated when any passenger Bridgeplate pushbutton is pressed, and shall remain illuminated until the bridgeplate function has been satisfied.

A Bridgeplate Deploy Request audible indicator shall be provided within the cab, to alert the operator of a request. The indicator shall be momentarily activated each time that a passenger Bridgeplate pushbutton is pressed.

6.13.4 Bridgeplate Enabled Illuminated Indicator

A green, Bridgeplate Enabled illuminated indicator shall be provided on the vehicle interior near the Bridgeplate Request passenger tapeswitch, along with associated graphics advising “Bridgeplate Enabled". The green LEDs around each passenger Bridgeplate Request pushbutton shall function as the Bridgeplate Enabled indicators at those locations; no separate graphics are required. The indicators shall be illuminated any time the door release control line for the respective side is energized.

6.13.5 Bridgeplate Audible Warning Signal

Repeating audible warning devices, mounted on or near the bridgeplate mechanism, shall be provided to warn of both bridgeplate extension and retraction. The beepers shall start functioning 2 seconds before bridgeplate movement and continue until extension or retraction has been completed. The beepers shall function only at bridgeplates where motion is commanded.

6.14 Trainlines

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

6.15 CDRL

The following design submittals are required:

6-1 Door System Design Package

a. General description, materials, drawings

b. Operator details and drawings

c. Lock and manual (emergency) release details

6-2 Bridgeplate System Design Package

d. General description, materials, drawings

e. Platform interface drawings

f. Operator details and drawings

g. Lock and manual release details

6-3 Door and Bridgeplate Controller and System circuit diagrams

h. Functional descriptions

i. Circuit schematics

j. Software design description

k. Software flow diagrams

l. Sneak circuit and single point failure analysis

i. Interlocks and safety critical functions

6-4 Door and Bridgeplate systems integration package

m. Location drawings and details of doors, bridgeplates, lights, warning indicators, and all switches, cutouts, and pushbuttons.

6-5 Diagnostics and Adjustments

6-6 Sensitive Edge and Obstruction Detection

6-7 Door and Bridgeplate Warning Indication

SECTION 7

HEATING, VENTILATING AND AIR CONDITIONING

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SECTION 7

HEATING, VENTILATING AND AIR CONDITIONING

7.1 General

The vehicle shall be provided with an air comfort system to automatically maintain the temperature and relative humidity conditions defined in this Section. Each operator cab and the passenger compartments shall be independently regulated.

The power source for the air comfort systems shall be three phase ac obtained from the auxiliary power supply described in Section 9.3. All components in the air comfort system shall be service proven in combinations and systems of comparable characteristics.

The requirements of this Section shall apply to both the passenger compartment and the operator's cabs.

7.1.1 System Design

The car builder shall perform heat loss / heat gain calculations of each interior space. All calculations shall be based upon recognized heating, ventilating and air conditioning industry criteria. These calculations shall take into consideration:

- The thermal transmission characteristics of the materials used in the car construction
- Outdoor ambient temperatures. Use the current edition of ASHRAE GRP 158 "*Cooling and Heating Load Calculation Manual*" to obtain climate conditions for cities within the United States
- For heating system, do not include on-board electrical loads, such as lights, in the heating calculations
- For air conditioning loads, include all on-board electrical devices adding heat to the compartment
- Assume the detrimental effects of exterior solar and wind conditions in all calculations, but assume no beneficial effects due to these outside influences
- Provide capacity in both heating and air conditioning to bring outside ventilation air to the desired interior temperature
- Assume AW2 passenger load for air conditioning calculations. Assume no passengers for heat calculations

7.1.2 System configuration

Except for floor heating, all heating, cooling, ventilation, and related controls shall be contained in independent unitized packages, or "HVAC units". The HVAC units shall be installed on the roof of the vehicle. The units shall be replaceable by bolted fasteners and multi-pin electrical connectors only; no fluid or refrigerant connections shall be required.

There shall be at least one HVAC unit for each vehicle body section with independent temperature regulation for each body section. Failures in one HVAC shall not affect operation of the other units.

Each operator cab shall have temperature regulation independent from the adjacent passenger section. Cab temperature regulation may be accomplished by a regulated air supply from the passenger compartment unit.

All HVAC functions shall be controlled by microprocessor-based control units or PLCs utilizing temperature sensors located as necessary in the vehicle to achieve specified temperature regulation and other performance requirements. The controllers shall be linked to the vehicle's data network, and provide status and diagnostics information to the network and operator's console. Refer to Section 17 for electronic controls, software, and maintenance diagnostic system requirements.

7.2 Ventilation

The air comfort system shall deliver fresh air to the vehicle in the amount of not less than 2.5 liters per second per passenger at AW2 load. Fresh air intakes shall be at roof level.

Ventilation of each carbody section of the vehicle shall be accomplished by the blower fans of the evaporator unit supplied as part of the air conditioning system. Air distribution shall be by ducts and diffusers. A positive static pressure of not less than 25 Pa (0.1 in. wg) and not greater than 37 Pa (0.15 in. wg) of water shall be maintained within a closed stopped or moving vehicle.

Full ventilation shall be continuously available in the event of refrigeration failure.

7.2.1 Air Distributions Ducts and Diffusers

An air distribution duct arrangement with ceiling mounted diffusers as approved by SDOT shall be provided. The main air distribution ducts shall be located in the car ceiling and shall be suitably insulated to minimize noise, heat transfer through the roof by direct conduction, and the formation of condensation. The ducting shall be non-flammable. The design shall meet the following criteria:

- Both supply air and return air shall be conveyed through dedicated and sealed duct work. Air leakage shall not exceed 2%, by volume, when measured at 20^0C (68^0F).
- Air distribution throughout the car shall be based upon the thermal loads calculated for the car interior space with air quantities delivered to properly offset these loads.
- Supply air shall be delivered to both sides of the car at ceiling level.
- Supply air delivery shall be through slot diffusers or multiple spot diffusers, but in no case shall concentrated air delivery create drafts such that passengers are made uncomfortable.
- Diffusers shall be adjustable and permit modulation of the airflow balance to eliminate temperature differences throughout the interior of the car.
- Air shall return to the HVAC unit through ceiling return air grills and shall be conveyed in dedicated ducts of the shortest possible length.

7.2.2 Air Filters

Air filters shall be provided for the return and fresh air to remove airborne dirt, lint, and other fibrous material. Filters shall be of a readily available commercial size. Filter frames shall accommodate both disposable paper filters and metal frame washable filters. Filter arrangement shall be designed for easy maintenance access. Filter manufacturer's recommended face velocity shall not be exceeded.

7.3 Heating Requirements

The vehicles shall be electrically heated by a thermostatically controlled system using overhead heat and floor heat. Both heating systems shall be powered by the three phase ac source.

The system shall have sufficient capacity to maintain interior temperature between 18°C and 22°C (64°F to 72°F) with an ambient temperature -8°C (18°F). Vehicle temperatures during heating shall be maintained without reliance on passenger heat contribution and solar loading as heat sources. The temperature of any heating equipment surface exposed to passengers shall be limited to 52°C (125°F).

7.3.1 Overhead Heat

Overhead heat capacity shall bring outside fresh air to car interior temperature without sensible cool air drafts. The heating elements shall be incorporated into the each packaged air conditioning unit. The overhead heat and controls shall modulate the heat to match the fresh air temperature for all heating conditions. The overhead heating elements shall also be used to provide reheat for dehumidification and cooling offset at conditions lower than design cooling conditions.

Size of heating elements shall be determined by the Contractor. However, the operator's cab units shall not be less than 2 kW, and the passenger cabin units shall not be less than 5 kW, each unit.

The control circuitry must have means to both regulate the required heat to the interior space and to prevent damage from excessive heat build up in the element plenum, such as may occur with loss of air flow. As a minimum, the following operating circuits shall be employed:

- The HVAC controllers shall regulate heater on / heater off to meet pre-set set points corresponding to the interior temperature requirements stated above. This circuit shall be fully automatic; and shall maintain interior temperature without intervention by the operator.
- Redundant high limit temperature sensors shall be installed adjacent to each overhead heater unit to detect the presence of excessive temperature. Upon detection of excessive temperature by either sensor, the heater shall be switched off and an indication provided to the controller and operator's console. If temperature cools below lower limit at both sensors, the circuit re-sets and the heater is switched on automatically.
- In addition to the heater circuit breaker, a back-up protection device in the form of a fusible link, or approved equal, shall be provided in the line to the overhead heat coils to remove power in the event of excessive current draw. A means to suppress the arc at rupture shall be provided as approved.
- In the event of a controller failure, the heating elements shall fail in the power off condition.

Overhead heater loads balanced between the three phases of the ac source.

7.3.2 Floor Heat

Floor heating shall be provided with sufficient capacity to compensate for all carbody heat loss through conduction and radiation without consideration of any internal car heat sources. The controls shall modulate the floor heat to avoid temperature fluctuations in the passenger area.

Floor heat shall be provided by baseboard convection units.

Floor heater loads shall be balanced between the three phases of the ac source.

7.3.3 Windshield Defrosting and Defogging

The car shall be equipped with electrical defrosting circuits embedded in the cab windshield. In the event of electrical system failure, the operator's cab heating system shall also provide for windshield defrosting and defogging. The system shall have sufficient capacity to defog the windshield with a -4°C (25°F) ambient temperature and a 20°C (68°F) interior dew point, (68°F) in a period not to exceed 15 minutes.

7.4 Air Conditioning

Air conditioning shall be provided by unitized roof-top cooling units utilizing a vapor compression direct expansion refrigeration cycle proven in transit service. The units shall not require the opening of any refrigerant piping for installation or removal of the unit from the vehicle roof. The refrigerant shall comply with current environmental regulations governing its use, handling, and recovery. The units shall use Hydrofluorocarbon (HFC) R-407C refrigerant or R-134a. Use of UV additives for leak detection is encouraged, but not a requirement if unproven in the experience of the equipment manufacturer.

7.4.1 Design Criteria

The vehicle shall be cooled and dehumidified by electromechanical equipment of adequate capacity to provide the required interior temperatures under the following summer design conditions:

Design Ambient Temperatures:	32°C DB (90°F)
	19.4°C WB (67°F)
Passenger Load:	500 Btu/hr per Passenger at 55% Sensible Heat Ratio.
Solar Load:	Follow ASHRAE Recommendations
Heating Load:	Total wattage of interior lights and vehicle equipment

During vehicle cooling, the interior temperature shall be maintained within the range of 22°C to 26°C (72°F to 79°F) and the relative humidity shall be below 60% with the design and less than design load conditions. For ambient temperatures above 32°C (90°F), the interior temperature may rise above the specified range, but shall maintain at least 6°C (10.8°F) below the ambient temperature. Car temperatures during cooling shall be maintained with an AW1 passenger load and maximum solar load based on worst case sun position and vehicle orientation.

7.4.2 General Design and Construction

Stainless steel frames, and drip pans are required. Non-structural enclosures may be stainless steel, aluminum, or fiberglass. Any fiberglass used in weather exposed conditions shall have appropriate UV inhibitors for twenty year life against break down in ambient sunlight.

Enclosures shall be designed with hinged covers that allow open access to all serviceable parts. Covers shall be capable of holding the load of a 12 kg (25 lb) tool box with damaging deformation.

Units are to be fully gasketed to prevent the ingress of rain and snow. All electrical terminations are to be made within the enclosure, and require seals at the cable penetration through the enclosures.

Refrigerant liquid lines shall have a serviceable or replaceable filter-drier and a sight glass with moisture indicator.

The refrigeration system shall be protected against explosion by a pressure relief device as recommended by UL Standard 465, Section 33. In addition, the system should meet the applicable requirements of UL 207: *Refrigerant Containing Components and Accessories.*

7.4.3 Compressors

Refrigerant compressors shall be powered by the three phase alternating current, and shall be fully hermetically sealed, scroll type design. Brand and type shall have been proven in rail transit service.

To reduce the possibility of refrigerant migration during off cycles, an automatic pump down circuit is required. The pump controlling circuit should generally include these steps:

- A tight closing solenoid valve must be placed in the main liquid line to each evaporator.
- Compressor must be allowed to continue to operate thru a low pressure switch, even when cooling is not required.
- An electrical interlock between the evaporator fan and the liquid solenoid valve must provided. The interlock may be accomplished by hardwired relay or software.
- A low pressure setting must be made such that the compressor cut-in point corresponds to a saturated refrigerant temperature lower than the ambient temperature to which the compressor is subjected to.

A compressor crankcase heater shall be employed if it is required to meet the compressor manufacturer's warranty.

Equipment shall have a means of capacity control. Whether single circuit or multi-circuited units are employed, capacity control must include evaporators, a thermo-expansion valve (for each evaporator circuit), and compressor capacity control. Equipment using capillary tubes instead of expansion valves shall not be accepted.

7.4.4 Evaporators and Condensors

Cooling coils shall be of corrosion resistant material and shall have a fin spacing facilitating cleaning for transit vehicle service conditions. Fins shall be capable of withstanding 175 kPa (25 psi) water or air pressure from a cleaning wand.

Tubes shall be intergrooved copper tubing with either copper or aluminum fins. Coil tube sheets shall have die-formed support collars for each tube.

Condenser coils shall be either acrylic resin coated or epoxy coated and have a minimum fin thickness of 0.12 mm (.005”). The minimum number of fins shall be equal to 10 per 25 mm (10 per inch). The finished gap between fins shall be not less than 2 mm (.079”).

Evaporator coils shall be either acrylic resin coated or hydrophilic surface treated and have a minimum fin thickness of 0.15 mm (.006”). The minimum number of fins shall be equal to 10 per 25 mm (10 per inch). The finished gap between fins shall not be less than 2 mm (.079”).

7.4.5 Air Conditioning System Piping and Fittings

Air conditioning refrigerant lines and condensate drain lines shall be type "K", seamless copper tubing, or ACR Rigid Copper; with wrought copper sweat type fittings. Joints shall be kept to a minimum and there shall be no inaccessible joints or fittings. Finned tubing in evaporators and condensers need not be type "K". Tubing may only be bent with an appropriate tube bending tool.

Suction lines shall be without traps and shall be sized for 20 kPa maximum pressure drop. The liquid line shall be sized adequately to prevent flashing due to pressure drop.

All condensate drain lines and suction line piping shall be insulated with an approved insulation that meets the smoke and flammability requirements of Section 16.14. The liquid line shall be insulated in all areas where required to provide additional mechanical or thermal protection. The insulating material shall be applied to the piping with suitable contact cement. All joints and directional changes in the insulation shall be appropriately mitered and sealed with an approved material.

All piping shall be de-burred after cutting and thoroughly cleaned after installation in accordance with this section. All piping and pipe subassemblies shall be cleaned, dried (if required), and capped on all openings after pre-fabrication. Caps shall remain in place until immediately prior to incorporation into the final assembly.

All inaccessible runs of tubing shall be without joints. Lines subject to sweating shall be insulated. Vibration eliminators shall be used in piping connections to the compressor. Tubing installations shall be designed such that any single length of tubing may be replaced without dismantling or removing surrounding equipment, piping, wiring or other appurtenances.

7.5 Controls

Car interior temperatures shall be uniform. During steady-state operation the interior temperatures shall not vary more than 2°C (3.6°F) between points in the same horizontal plane of the vehicle, and shall not vary more than 3°C (5.4°F) between any point 100 mm above the floor to 1700 mm above the floor in a vertical plane. Air comfort controls shall be provided to automatically activate appropriate operation modes to achieve the specified temperature and humidity inside the vehicle depending on ambient and vehicle interior conditions. The controls and systems shall be designed for energy-efficient operation, reliable operation, and easy maintenance.

Air comfort controls shall be activated automatically when an operators’ console is activated. De-activation shall include a time delay to accommodate changing ends or an in-service layover.

The controls shall provide status and fault indication displays, located for convenient observation by maintenance personnel. Operator warning indications shall also be made to the operator if immediate service is needed.

7.6 Manufacturing Requirements

As a minimum, the supplier of the equipment shall have an ISO 9000 certified factory quality control program.

The Contractor shall assure compliance with the supplier's complete instructions for the receiving, storage, lifting, installation, and commissioning of all equipment.

7.6.1 Silver Soldering of Refrigerant Lines

Soldering of copper type K -and/or- ACR pipe and fittings shall be performed to AWS A 5.8 or the equivalent standard used in the country of equipment origin (i.e.: AWS A 5.8, welding procedure Bag-5 is commonly used on refrigerant pressure lines in the U.S.).

For refrigerant pressure piping the silver content of the filler metal shall be between 35% and 45%. Filler metal used on refrigerant piping shall be Cadmium free.

For non-pressure return lines the silver content shall be between 5% and 15%.

All copper piping shall be mounted in such a way that shock and vibration will not cause failure of the solder joints. All equipment and piping shall meet the criteria of IEC 61373 (EN 61373): "*Random Shock and Vibration Testing*".

7.7 Air Conditioning System Test and Charging

Each self contained air conditioning unit shall be charged and tested at the factory, prior to shipping to the car builder. In-factory testing shall include functional testing of control systems and unit output.

System charging shall be performed to the manufacturer's own procedure; but as a minimum, must incorporate these steps:

- Connect a drum of refrigerant to charging connection and introduce enough refrigerant into system to raise the pressure to 70 kPa (10 psi) gage. Close valves and disconnect refrigerant drum. Test system for leaks with halide test torch or other approved method suitable for the test gas used. Repair all leaking joints and retest.
- Connect a drum of dry nitrogen to charging valve and bring test pressure to design pressure for low side and for high side. Test entire system again for leaks.
- Evacuate the entire refrigerant system by the triplicate evacuation method with a vacuum pump equipped with an electronic gage reading in mPa (microns). Pull the system down to 665 mPa (500 microns) and hold for four hours then break the vacuum with dry nitrogen (or refrigerant). Repeat the evacuation two more times breaking the third vacuum with the refrigeration to be charged and charge with the proper volume of refrigerant.
- Under no circumstances allow a refrigerant and air mixture to enter the system.

Final assemblies shall meet the leak tightness requirements of SAE J-2727: "*Leak Tightness Testing*"

7.8 CDRL

The following submittals are required:

7-1 Design calculations for heat gain / heat loss in both the operator and passenger cabins (Section 7.1)

7-2 Manufacturer's data on air filter: including brand, type, size and quantity (Section 7.2)

7-3 Overhead heating ductwork and diffuser drawings. Include airflow velocity and pressure drop calculations (Section 7.3.1)

7-4 Carbuilder's design drawings and data for floor heating system; including manufacturer's data on all heating elements (Section 7.3.2)

7-5 Carbuilder's design drawings and data for auxiliary forced air defrosting system (Section 7.3.3)

7-6 Supplier's submittal for all A/C Units (operator's cab and passenger cabin units); include all component identification, all materials identification, general layout drawings, electrical and controls schematic, and piping schematic. Identify make and model number for compressor, and all purchased sensors and instrumentation (Section 7.4)

7-7 Complete control schematics; functional description of controls; and brand(s), type, and model of PLC and control devices (Section 7.5)

7-8 Certifying letter of manufacturer's ISO 9000 quality program (Section 7.6.1)

7-9 Description of all fastening and joining methods for refrigerant piping; including Silver Solder procedures (Section 7.6.2)

7-10 One in-factory test booklet, per unit. Booklet must contain results of controls functional testing, performance testing, charging certification, and leak testing (Section 7.7)

SECTION 8

LIGHTING

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SECTION 8

LIGHTING

8.1 General Description

The lighting system design and illumination requirements shall meet Federal Regulation CFR 38 subpart D, APTA SS-E-013-99, and APTA RP-E-012-99 for vehicle lighting. Additionally, exterior lighting shall conform to Federal Regulation 49 CFR 571.108 for vehicles of 80 inches (2032 mm) or more over all width. Where a conflict exists, the most restrictive requirement shall apply.

All lighting, except for headlight and interior fluorescent, lighting shall be LED. All lighting shall, be powered from the low voltage dc system, and designed to withstand conditions typical of the rail transit environment in the Seattle area, as described in Section 2.2.4.

All lighting fixtures shall be designed to provide ease of installation, cleaning, lens, lamp and ballast change-out, adjustment,; and housing removal. Fixtures installed on the vehicle exterior and in the interior within 600 mm of a doorway shall be watertight except for interior ceiling lights.

Power wiring to the lamp fixtures shall be insulated from carbody ground. Lighting systems shall not use the fixture housings or sockets as a ground return. All fixtures and their exposed metallic surfaces shall be grounded to the vehicle structure.

The Contractor shall submit a Lighting System Design Package (CDRL 8-1), for SDOT review and approval. The design package may be submitted as two packages, exterior and interior, lights.

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

Fluorescent lighting shall be used as general overhead lighting in the passenger areas. However, alternative lighting arrangements will be considered, such as LED 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 APTA RP-E-012-99, Section 12.5 Fluorescent fixtures and Section 12.8 Lamps.

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 2.3.2.

With the exception of LEDs used as indicators on circuit boards, the use of single LEDs is prohibited; single high powered LEDs, will need approval from SDOT. All LED assemblies shall be designed such that the failure of one LED is visually indicated to maintenance personnel. 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.

Electronic controllers shall comply with the design requirements stated in Section 17.

8.3 Interior Lighting

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

The light, fixture, and associated parts or equipment shall meet the flammability and smoke emission guidelines specified in Section 16.14.

8.3.1 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. Each row of light fixtures shall be powered by a separate circuit; fixtures across the aisle shall be connected to different circuits.

A minimum of one standard length emergency light fixture shall be located at each door area. See below for other emergency lighting requirements.

8.3.1.1 Passenger Area Light Intensity

The average intensity of the illumination within the car, at an elevation of 850 to 1675 mm above the floor, shall be at least 350 lux, at the nominal rated voltage.

The average light intensity at the floor in the passenger aisles and articulation section shall not be less than 215 lux.

The average light intensity at the car entrances and exits within 500 mm of the doors shall not be less than 215 lux at the floor.

8.3.2 Doorway Floor Lights

White color lights shall be provided at each doorway for threshold and platform illumination, located so that they will provide, at minimum, 54 lux of illumination. The intensity shall be measured on the surface of the platform, at any distance from the side of the vehicle and 1 m away from the vehicle side in the horizontal direction.

The light shall be illuminated when the passenger door starts to open and shall be extinguished when the door is closed and locked.

8.3.3 Stairway Floor Lights

White color lights shall be provided at each stairway for step illumination, providing at minimum 54 lux of illumination measured on the surface of the steps.

The lights shall be illuminated when the interior lights are on and shall be powered by the emergency light circuit.

8.3.4 Operator's Cab Light

Each cab shall be provided with a light fixture suitably placed in the ceiling to illuminate the operator's console. The light beam shall be placed to avoid glare on the windshield. The average illumination intensity measured on the operator's controls shall be 200 lux.

The cab light shall be controlled from a switch on the operator's console that shall function only when the local operator's console is powered. At all other times, the light shall be extinguished.

8.3.5 Console Light

Each cab console shall be illuminated to enable the operator to see the console labels, pushbuttons and switches under varying lighting conditions. The console light shall be mounted at the top edge of the console and shielded from the operator's eyes. When illuminated, the console light shall not cause glare on the windshield.

The console light shall be energized automatically when the operator's console is powered. A dimmer control shall be provided for variable adjustment of the brightness. At all other times, the light shall be extinguished.

8.4 Exterior Lighting

Exterior lighting assemblies shall be set in waterproof enclosures. All bezels and trim shall be made of either aluminum or stainless steel, have captive stainless steel fasteners, and be consistent with good mechanical mounting principles.

Headlights, taillights, stoplights, turn signals, and clearance and marker lights shall conform to Federal Regulation 49 CFR 571.108 for vehicles of 80 inches (2032 mm) or more over all width.

8.4.1 Headlights

Two (2) replaceable bulb halogen headlamps, one for high beam and one for low beam, meeting the performance requirements of SAE J2560, shall be provided on each side of each end of the vehicle. Lamps may be standard automotive 12v lamps, or 28v truck/bus lamps. Voltage at the lamp shall be derived from low voltage dc source, and shall be as recommended by the lamp manufacture for stated lamp life. 12v nominal lamps shall be powered by dedicated dc-dc converters, one per vehicle end.

Headlights shall be on in the leading end of a train only, regardless of which cab in the train is powered.

A high beam indicator light shall be provided on the console and it shall be illuminated any time the console is powered and the adjacent headlights are switched to energize the high beams.

The headlights shall be adjustable to permit proper aiming of the beams.

8.4.2 Tail Lights and Stop Lights

Two (2) red taillights meeting the requirements of SAE J2040 shall be provided at each end of each vehicle. They shall be illuminated as follows:

- At both ends of a vehicle whenever the auxiliaries are ON and no direction is selected;
- At the trailing end of a vehicle whenever a direction has been selected, by placing one reverser switch in FORWARD or REVERSE, as determined by the forward and reverse directional control lines, which shall also cause the taillights on the leading end of the train to extinguish.

The taillights shall not be illuminated at any other time. When illuminated, the taillights shall be plainly visible from a distance of not less than 150 m.

Two (2) stoplights meeting the requirements of SAE J2261 shall also be provided per end. The stoplights shall be illuminated on the trailing end of a vehicle, as determined by the forward and reverse directional control lines, when the vehicle is powered with the reverser switch in FORWARD or REVERSE, and either the: dynamic, friction, track, or parking brakes are applied.

8.4.3 Marker Lights

At least one amber marker light meeting the requirements of SAE J2042 shall be provided near each end corner of the vehicle. When illuminated, each marker light shall be plainly visible from a distance of not less than 150 m. They shall be illuminated whenever the auxiliaries are ON. At all other times the marker lights shall be extinguished.

8.4.4 Turning Direction Lights

Flashing turn signals shall be provided on the front, sides, and rear of a vehicle. The front and rear turn signals shall meet the requirements of SAE J2261, and the side turn signals shall meet the requirements of SAE J2039. When illuminated, each turn signal light shall be plainly visible from a distance of not less than 150 m.

The turn signals shall be controlled from a three-position switch located on the operators' console. The center position shall be the neutral and it shall function as OFF. The other positions shall be LEFT and RIGHT, respectively.

8.5 Emergency Lighting

The emergency lighting system shall comply with the minimum performance requirements of APTA-SS-E-013-99. The average intensity of illumination within the passenger area of the car shall be 22 lux, measured 640 mm above the floor.

The following lights shall be powered from the low voltage system and shall remain on or available after the loss of high voltage power to the converter:

- All doorway floor and overhead lights
- Operating cab console and lights
- All exterior lights, required per Section 8.4, Federal Regulation 49 CFR 571.108.

The Contractor shall submit an Emergency Lighting System Design Package (CDRL 6-2) for SDOT review and approval.

8.6 Lighting Sources

All lamps, Fluorescent lamp sockets, and ballasts, shall be considered as consumable items, shall be commonly stocked and available from US suppliers.

8.7 CDRL

The following design submittals are required:

8-1 Lighting system design package

a. Verification of lighting performance by analysis.

b. Drawings of all lamp fixtures.

c. Drawing of the vehicle showing all light fixture locations and identities.

d. Listing of all lamps by function, type, part numbers, and source of U.S. supply

e. Warranty information for all equipment, including LED lamps

f. Schematics of lighting circuits, including emergency lighting

   i. Functional description

   ii. Lighting schematics

   iii. Software design description

   iv. Software flow diagrams

8-2 Emergency lighting system design package

g. Emergency lighting analysis and drawings

h. Verification of emergency lighting load analysis

SECTION 9

AUXILIARY ELECTRICAL EQUIPMENT

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SECTION 9

AUXILIARY ELECTRICAL EQUIPMENT

9.1 General

This section specifies general electrical equipment not specifically related to propulsion, HVAC, or other electrical systems. Included are the overhead power collection system, power distribution, grounding, ac and dc supplies, and similar equipment and systems.

No high voltage equipment may be installed inside the passenger compartment. All enclosures shall comply with isolation and fire safety requirements stated in NFPA 130.

All equipment on the vehicle, including the truck frame, all resiliently mounted apparatus, and all truck mounted equipment, shall be safety grounded to the car structure. The car structure shall be safety grounded to the axles. Refer to Section 11.

The Contractor shall submit 90 days after NTP dedicated one-line power distribution diagrams for primary, ac, and dc loads, for SDOT review and approval. (CDRL 9-1) The diagrams shall show loads, return current paths, protections and grounds.

The Contractor shall submit 90 days after NTP the format of and proposed schedule for submittals of the current load integration report correlated with but not limited to the one line diagrams required above, for SDOT review and approval. (CDRL 9-2)

The Contractor shall submit 120 days after NTP the first current load integration report and continue to submit the reports quarterly, according to the approved schedule, for SDOT review and approval. (CDRL 9-3)

9.1.1 Safety Grounding

All equipment on the vehicle, including resiliently mounted equipment, enclosures, the truck frame, and truck mounted equipment, shall be safety grounded to the vehicle structure. The vehicle structure shall be safety grounded to the axles. Specific requirements appear later in this Section and Section 16.20.5.

The Contractor shall submit a complete grounding scheme for SDOT review and approval. (CDRL 9-4)

9.1.2 Circuit Protection

All low voltage dc circuits and ac circuits shall be individually protected by circuit breakers except where otherwise specified. Circuit breaker terminals shall not be used as junction points. All circuit breakers shall be sized to protect both the equipment and the minimum wire size used for power distribution within the protected circuit. Fuses are not permitted in low voltage dc and ac applications except where specified or approved. Ac and low voltage dc circuit breakers shall be mounted in panels in the operator's cab. Refer to Section 16.22.6 for circuit breaker panel design requirements.

High voltage dc circuits shall be protected at the pantograph interface level by high speed dc rated circuit breakers or fuses, as required elsewhere in this Specification. Primary distribution circuits in the vehicle shall be individually protected by high voltage dc rated fuses mounted in insulated self-extracting fuse holders.

Local circuit protection shall be coordinated with main source protection such that faults or overloads downstream of the local protection shall trip the local protection, and not trip the main source protection. Local protection trip settings shall be lower than the main source power or current limit settings.

All equipment operated from the Overhead Contact System (OCS) shall be rated for continuous operation at the maximum OCS voltage, as described in Section 2.3.1.

9.1.3 Return Circuits

The vehicle structure shall not be used as a normal circuit return path for any electrical equipment.

The primary return circuits shall be grounded to the axles per the requirements of this Section.

The low voltage dc return circuits shall not be grounded to the vehicle structure at any location, except at a single point common to the battery and LVPS. This ground connection shall be by a RC network.

The ac neutral shall be single point grounded.

Each system or circuit fed from a circuit breaker or fuse shall have its own return wiring. Each circuit return wire shall be connected, via its own separate terminal, to a return bus located in the same electric locker that contains the circuit breaker that supplies the circuit.

9.2 Primary Power System

9.2.1 Pantograph

All vehicle power shall be collected from the overhead contact system (OCS) by a roof-mounted upward pressure sliding pantograph. The operating range of the pantograph shall comply with Section 2.

The pantograph shall be a service-proven, single-arm design, with a spring supported double carbon contact assembly capable of stable bi-directional operation at all specified vehicle speeds and external system characteristics.

The contact assembly shall contain replaceable curved carbon inserts of one-piece design. The carbon surfaces in contact with the OCS shall have a lateral radius of 6 m to 10 m, or other approved value. The contact assembly, and the carbon inserts, shall be individually replaceable with common hand tools.

Contact force on the contact wire shall be selected for optimum tracking and minimum wear, but shall be no greater than 110 N at the maximum adjustment range. Contact force shall be adjustable and shall not vary by more than 25 N over the combined full ranges of operating height, vehicle speed, and direction. Pantograph dynamic stability shall be sufficient to preclude un-intentional lock-down when negotiating downward wire ramps at speed.

A mechanism shall be provided to automatically restrain the pantograph in the fully lowered position. The mechanism shall function at all times regardless of failures in power, control, or other system elements. The mechanism shall be released automatically when the pantograph is commanded to be raised.

The pantograph shall be spring raised when the restraining mechanisms are released. The raising speed shall be damped or otherwise controlled to prevent carbon strip damage upon striking the contact wire. This speed control shall be active at all times except during normal wire tracking.

The pantograph raising and lowering circuit shall be operable from either cab, by a console mounted Pantograph Up/Down Switch, but only while the train is at rest or moving in a coast or brake mode only. Lowering of the pantograph shall not affect a requested brake rate and shall result in a coast mode if the vehicle is in a coast or power mode. Electric raising and lowering mechanisms shall operate throughout the voltage range specified for all low voltage equipment.

An energy storage control interface shall be provided to automatically lower before entering wireless operation and automatically raise the pantograph when on wire operation is to resume, see Section 9.6.

Provision shall be made for manually lowering and raising the pantograph in the event of a loss of power or control. These manual mechanisms shall be operable from, and stored within, the vehicle, but shall be accessible only to the operator.

The Contractor shall prepare a design report on the pantograph, including data to support the ratings of the components, data sheets on each component, parts lists, electrical drawings and assembly drawings for SDOT review and approval. The Contractor shall include the pantograph dynamic envelope as a dedicated section in the design report, and shall show that the pantograph does not lose contact with the wire under normal and abnormal operating conditions identified in this Specification. (CDRL 9-5)

9.2.2 Primary Circuit Protection

Adequately rated overvoltage protection, current sensing, fault clearing devices, and any other circuit protection deemed necessary by the Contractor shall prevent damage to auxiliary and propulsion system components.

Auxiliary circuits are defined as all line voltage operated systems other than the propulsion circuits. Auxiliary circuit protection may be provided via a high speed fuse with a voltage rating of not less than 1000 Vdc.

Propulsion circuit protection shall be provided by an electrically resettable high speed circuit breaker (HSCB). Resetting of the high speed circuit breaker shall be possible from each driver's cab. The HSCB shall protect all propulsion equipment except for the lightning arrestor, which shall be in the circuit before the HSCB. Refer to Section 16 for HSCB requirements.

A dry-type lightning arrestor shall be mounted on the roof, on or adjacent to the pantograph base. The arrestor shall be rated by the manufacturer for outdoor dc operation. The arrestor shall be rated to prevent any voltage transients and surges from damaging or degrading carborne equipment, including the arrestor itself.

Instead of a shop switch, other means of safely isolating all high voltage circuits from the catenary while providing high voltage shop power to the APS/LVPS may be submitted to SDOT for approval. (CDRL 9-6)

9.2.3 High Voltage Shop Switch

An enclosed, rotary, manually operated shop switch shall be provided to enable shop personnel to connect shop HV power to the vehicle auxiliary circuits, providing power to the vehicle for HVAC, lighting, and all other loads except propulsion. The switch shall provide positive indication of the switch position.

The shop switch shall include interlocks to disconnect loads to prevent operation under load in case the maintenance person does not lower the pantograph or disconnect shop power before operating the switch. The design shall require that the switch handle be pushed toward the box

before the switch can rotate. This action shall open interlock switches that shall be used to disconnect the high voltage auxiliary and propulsion circuit loads.

Primary power shall be supplied to the shop switch by a plug-in cable (stinger) from the maintenance shop. A receptacle on the shop switch shall mate with the plug on the shop cable, as defined by SDOT. Auxiliary contacts shall be provided on the plug and receptacle which break prior to the breaking of the main power contacts, when removing the plug. The Bombardier part number for the plug is 409P190H48.

The switch shall have three positions: Normal, Auxiliary, and Off:

- Normal: Connects the vehicle auxiliary circuits to the pantograph circuit for normal operation, and disconnects the receptacle from the vehicle circuits.
- Auxiliary: Connects shop power to the vehicle auxiliary circuits without energizing the propulsion system or the overhead contact wire, pantograph, or pantograph frame.
- Off: Disconnects all vehicle circuits from the pantograph circuit, and disconnects the shop receptacle from all vehicle circuits.

Auxiliary circuits in this case is defined to include charging both the control voltage and energy storage batteries.

The switch contacts shall be sized for the maximum continuous and peak auxiliary currents. The switch shall be mounted in a non-metallic enclosure easily reached from the side of the vehicle at roof level. Operation of the switch shall not require opening of the enclosure or exposure of personnel to any high voltage conductors.

The connection for the shop cable shall include a hinged cover with latch.

The installed shop switch shall be watertight when subjected to a water test equal in severity to that for the carbody.

The Contractor shall prepare a design report on the shop switch or alternative arrangements, including data to support the ratings of the components, data sheets on each component, parts lists, electrical drawings and assembly drawings for SDOT review and approval. (CDRL 9-7)

9.2.4 Ground Brushes

Ground brushes and contact elements shall be provided for primary current return to the running rails by using the wheels and appropriate visible shunts around the wheel resilient elements. The arrangement shall prevent any current return through the journal bearings, gear units, or motor bearings.

Ground brushes shall be provided for safety grounding the car body and truck equipment. Safety ground brushes shall be separate from those used to carry primary current.

Ground brushes shall be provided for each wheel or for each through (not stub) axle in a conventional truck. The ground brushes shall be rated to carry 2.0 times the circuit rms current, and 1.5 times the circuit peak current.

Ground brush life shall be no less than 500,000 km.

The Contractor shall submit a design report including a description of the ground brushes, drawings for the hardware and a circuit diagram showing ground brush arrangements and ground connections. (CDRL 9-8)

9.2.5 Line Filters

Line filters may be individual elements of various systems that are fed by the primary power, or may be combined provided that system isolation switches or contactors are supplied to permit independent operation of each supplied system. Although these filters may be elements of individual systems, they are described here to eliminate duplicate specifications.

Line filters shall filter the voltage applied to the power components of the auxiliary electric, propulsion, and any other system connected to the OCS, which voltage may interfere with external systems. Line filters shall suppress high frequency voltage transients caused by IGBT switching operations.

The resonant frequency of each filter shall be less than 60 Hz, and shall be inductive above 55 Hz.

Capacitors shall have a rated life of at least 15 years.

Provision shall be made for automatic detection of filter failures resulting in excessive EMI, particularly at signal system operating frequencies. Detection of such failures shall automatically inhibit propulsion, annunciate a propulsion failure, and store the data in the propulsion failure log. The detection scheme shall meet the safety requirements of Section 2 and shall be submitted for approval. (CDRL 9-9)

Electrolytic capacitors shall be fused and shall have blown fuse indicators readily visible without necessitating the removal of components. Capacitors with rated lives less than twenty years shall be readily replaceable without soldering or disassembly of other components.

A bleeder resistor shall be permanently connected across the terminals of each capacitor in the capacitor bank. The resistance value shall be selected to reduce the voltage at the terminals of the capacitor bank to 50 V or less within 3 min after primary voltage is removed from the bank. A permanent sign shall be positioned adjacent to the capacitors to warn maintenance personnel to lower the pantograph, wait 5 min, manually bleed, then short circuit the capacitor before commencing work. The sign shall be visible when the door to the enclosure which houses the capacitor bank assembly is open.

9.2.6 Ground Fault Protection

The vehicle shall provide ground fault protection at the inputs of all high voltage dc circuits, and for all ac convenience outlets. The detection schemes and sensitivity levels shall be submitted for approval.

9.3 AC Power Supply

Auxiliary electrical power conversion shall be accomplished by one or two independent dc-to-ac inverters, powered from the overhead catenary system and supplying power to the ac auxiliary loads. Each inverter shall supply the loads for either the complete car or in its respective car half (see Failure Management, below). The output of the inverter(s) shall be electrically isolated from the primary power system. Refer to Section 2.3.3 for output voltage and frequency requirements. Refer to Section 17 for electronic controls, software and MDS design requirements.

The inverter(s) shall start automatically and provide full performance when the steady-state input voltage is as specified in Section 2.3.4. The inverters may shut down when the steady-state input voltage is less than greater than the range specified in Section 2.3.4.

The inverters shall be sized for the worst case continuous operation of all loads, and the maximum peak individual load with all other steady-state loads applied.

The auxiliary inverter shall provide the output voltages as specified in Section 2.3.3, with the 3-phase output in compliance with the following requirements:

- Output frequency tolerance: +/- 2%
- Distortion under nominal load: < 10%
- Maximum dv/dt of the output voltage: < 10V/µsec
- Maximum allowable phase current imbalance: > 50%

The controls for the inverters shall prevent damage both to auxiliary equipment, and the inverter itself, resulting from:

- High and low frequency
- Over and under voltage
- Out of tolerance voltage-to-frequency ratio
- Frequent repetitive starts (manufacturer defined limits)
- Rapid variations and transients in line voltage or loads
- All primary power interruptions
- Excessive harmonic distortion
- Phase loss

The control logic shall permit the equipment to automatically restart for shutdowns caused by self-correcting failure conditions. Major faults shall latch the equipment off until reset by maintenance personnel.

A fault monitoring system shall be provided to automatically detect the inverter status and transmit the information to the operator's cab via the vehicle network. Refer to Section 17.

The Contractor shall prepare a design report on the auxiliary power supply and associated loads to justify the selected configuration and to confirm compliance with the requirements of this Specification for SDOT review and approval. It shall include load analysis, description of how the equipment operates under extreme conditions and faults, ratings sheets, software descriptions, electrical schematics drawings, and assembly drawings. (CDRL 9-10)

9.3.1 Failure Management

Loss of a single ac inverter shall not result in loss of propulsion or other functions critical for vehicle operation.

For the case of a car equipped with two inverters, the event of an inoperable ac inverter, provision shall be included to transfer ac power for the essential loads to the second or a back-up inverter. As a minimum all safety and vehicle operation related functions must be kept operational, so that a vehicle with a failed ac inverter can be operated over the whole alignment on its own power from the remaining ac inverter to the circuits in the other body section for propulsion ventilation, and other ac loads as may be required by the propulsion system.

Critical friction brake loads, where permitted to be powered by ac, shall also be transferred.

The ratings of each ac inverter shall include these redundancy transfer loads in addition to the loads of its respective body section.

The transfer mechanism may be via three-phase transfer breakers, or other approved methods.

For the case of a car equipped with one inverter the critical loads, including propulsion blowers and pumps shall be operated from the cars low voltage dc system. Critical blowers and pumps shall be provided with brushless dc motors.

The Contractor shall submit a fault management design report to SDOT for review. (CDRL 9-11)

9.4 Low Voltage DC Power System

A source of low dc power shall be provided for specified vehicle loads, and for battery charging. Refer to Section 2.3.2 for specific voltage range and design requirements.

The low voltage power system shall include circuitry to detect LVPS and battery charging failures. The circuit shall provide fault indications to the operator's cab via the vehicle's network. Refer to Section 17 for electrical controls, software and MDS design requirements.

The Contractor shall submit a low voltage system report for review. (CDRL 9-12)

9.4.1 Low Voltage Power Supply

There shall be one or two independent low voltage power supplies (LVPS) for each vehicle. Battery charging shall be controlled independently of the DC load output.

The LVPS shall be a regulated dc power supply powered either from the ac inverter or from a dc source which may be either the catenary supply or an intermediate voltage pre-regulating power supply. If the car is supplied with only one auxiliary inverter the LVPS shall be supplied from a dc source. Designs which include the LVPS as part of the auxiliary inverter will be acceptable. If combined, operation or failure of the LVPS shall not affect operation of the ac inverter. The LVPS shall provide complete electrical isolation of the output from the primary power system.

Each LVPS or LVPS output channel shall have sufficient capacity to charge a dead battery while simultaneously providing nominal voltage to the low voltage dc loads of all vehicle loads, for all body sections, with the assumption that the other LVPS or output channel is not functioning. Transfer of loads to one LVPS with the loss of the other LVPS shall be automatic, and not require any action by SDOT personnel. When the failed LVPS resumes operation the load transfer control shall detect this and automatically restore operation and load distribution between the two LVPS units.

The LVPS shall automatically start when primary power is applied. Battery power shall not be required as a prerequisite to starting, or for closing circuit breakers or contactors needed to permit LVPS operation.

The Contractor shall submit a low voltage power supply and battery charger report for review. (CDRL 9-13)

9.4.2 Control Voltage Battery Charging

The control voltage battery shall be charged via a dedicated battery charging circuit that is part of the LVPS. It shall include a current limiting feature that ensures the battery manufacturer's recommended charging current level is not exceeded.

The battery charging voltage shall be optimized for the battery selected by the Contractor, per the battery manufacturer's recommendations. The charging voltage shall be adjustable by the user.

Battery charging shall utilize constant current control to charge empty or partially discharged batteries and constant voltage control to float charge the batteries. Both charging controls shall be automatically adjusted for battery temperature via a temperature sensor in the battery compartment.

9.4.3 Control Voltage Storage Battery

A storage battery shall provide back-up power emergency loads. The battery may be configured in a single package, or as two assemblies, one for each carbody section.

If a single battery per vehicle is provided, it shall be possible to charge the battery from either LVPS in case of an LVPS/Battery charging failure. Switch-over circuit shall be automatic, or via a dedicated manual circuit.

The battery shall be a low maintenance NiCd type, service proven railway or transit quality battery.

The battery shall be installed in a ventilated compartment, under the vehicle, and outside the passenger compartment. The battery assembly shall be mounted in a stainless steel, ball-bearing supported roll-out tray. The tray extension shall be of sufficient depth to permit the battery to be fully extended such that all cells may be inspected and filled.

Roof mounted batteries may be proposed but are subjected to SDOT approval.

The battery compartment arrangement shall be large enough to accommodate batteries from at least two independent suppliers.

A circuit breaker shall be provided for battery and battery circuit protection. The circuit breaker shall be a two pole, explosion proof breaker mounted in the battery box or of non-explosion proof design located in an electric locker within 10 ft (3 m) of the battery box. Parallel breakers are not permitted. The circuit breaker shall be rated to withstand the short circuit capacity of the battery and shall be connected into the B+ and B leads from the battery terminals.

The battery shall be equipped with a fire alarm system for heat and smoke detection and be arranged to trip the battery circuit breaker upon detection of an excessive heat or smoke. As required by NFPA 130-2010 Chapter 8.6.9. The temperature setting shall be as recommended by the battery manufacturer.

An accessible battery cut-out switch shall be provided if the battery circuit breaker is not accessible from the side of the vehicle or at a convenient interior location, as required by NFPA 130-2010 Chapter 8.6.9.

The Contractor shall submit a battery design report. It shall include the battery description and specification, recommended charging processes, circuit breaker, over-temperature setting, emergency load calculations and assumptions, and mounting location. (CDRL 9-14)

9.4.4 Emergency Power

Emergency power shall be provided by the battery, in the event of loss of LVPS units or outputs.

The battery shall be sized for provide either of the load conditions described below (9.4.4.1 or 9.4.4.2), whichever is the worst case.

9.4.4.1 Emergency Vehicle Power

The control voltage battery capacity shall be able to supply all the loads below for a period of 45 minutes without discharge to below 1.0 V per cell.

- Emergency Lighting (continuous)
- Door Control (cycle doors open for 20 seconds every 5 min)
- Propulsion Control (continuous)
- Braking Power and Control, including pumps if dc operated (continuous)
- Operator's Console Indicators and Interlocks (continuous)
- Horn and Bell (on for 10 seconds every 2 min)
- Track Brakes (on for 20 seconds at end of each 20 min period)
- Pantograph Control (raise and lower twice)
- Headlights, tail and stop lights (continuous)
- Windshield Wiper (continuous)
- Passenger Information System

All indicated loads and systems shall have sufficient input voltage to complete the run. If adequate voltage cannot be provided to vehicle controls by the battery for the defined run conditions, dedicated dc-dc converters shall be provided to raise control voltages to adequate levels at the loads.

9.5 Auxiliary Electrical Distribution

Auxiliary circuits are defined as all non-traction, power generation, and distribution circuits. Distribution circuit protection shall be branched in a logical organization to facilitate fault isolation and shall minimize any operational impacts on other systems.

All circuits shall be protected by circuit breakers. Fuses may be used only where specified in this document and where applicable circuit breakers are not commercially available.

All circuit breakers and fuses shall have permanent labels installed adjacent to the device.

All low voltage dc control breakers shall be grouped logically on a breaker panel in each cab. Ac loads that are in the cab shall have their respective breakers in the cab. Other ac distribution breakers shall be located within the vehicle such that they may be readily inspected by the operator, but not accessible to passengers.

The main battery circuit breaker(s) shall be located under the vehicle, adjacent to the battery and readily accessible from the side of the vehicle.

All overhead catenary system voltage circuit breakers and fuses shall be mounted on the vehicle roof. High voltage fuses shall be mounted in totally enclosed fuse holders with no exposed high voltage connections. The fuse shall be extracted from the circuit when the fuse holder is opened and the exposed fuse shall be safely isolated from any circuit connection.

Except for the shop switch described in this section, there shall be no high voltage dc switches capable of manual operation. All high voltage dc circuits shall be manually interrupted by either activating the respective circuit breaker or activating a low voltage switch which subsequently controls a high voltage contactor.

9.6 Onboard Energy Storage System (OESS) For Wireless Operation

9.6.1 General

The vehicle shall be equipped with at least two onboard energy storage systems, at least one per truck, with the combined capability of operating the vehicle over the profiles specified in Section 2. Auxiliary loads shall be split between the two systems.

If the OESS uses energy storage batteries they also shall be charged when the car is powered through the shop auxiliary power cable (stinger).

Refer to Section 17 for electronic controls, software and MDS requirements.

The Contractor shall prepare a design report on the energy storage systems and associated loads to justify the selected configuration and to confirm compliance with the requirements of this Specification. It shall include load analysis, description of how the equipment operates under extreme conditions and faults, ratings sheets, software descriptions, electrical schematics drawings, and assembly drawings. (CDRL 9-15)

9.6.2 Energy Storage Functions

The systems shall include the following:

1. The energy storage device may be composed of capacitor or battery cells arranged to produce a high voltage storage device.
2. A control unit shall be provided to interface with the propulsion, auxiliary power system, and HVAC system for the purpose of controlling energy storage device connections to those systems and monitoring the state of the energy storage device. This may be combined with the propulsion system logic.
3. The system shall interface with the TWC system (Section 13), at specific locations along the right of way which define the wireless segment(s), such that operation through the wireless segments can be accomplished without operator intervention. The system shall include automatic controls to drop and isolate the pantograph circuit from the car high voltage bus before entering areas where wireless operation is required and to automatically raise the pantograph and reconnect it to the car high voltage bus when on wire operation is to be restored.
4. A Wireless Operation Switch on the operator console shall permit manual control of wireless operation by the train operator, in the event that automatic operation malfunctions, or wireless operation is required at other locations. The Wireless Operation Switch shall be located adjacent to the Pantograph Up/Down Switch. The Wireless Operation Switch shall not automatically lower/raise the pantograph.
5. Wireless operation shall be interlocked with the pantograph such that wireless operation can only be activated or deactivated if the pantograph is down.
6. Wireless operation mode shall be annunciated on the driver's console, see Section 5.
7. A bi-directional converter (chopper) shall be provided to both charge the energy storage device and control energy storage power flow to the auxiliary power system and propulsion system. This could be packaged with and share components with the propulsion system.
8. Components shall be provided to monitor and balance storage device cell voltages to prevent damage to cells due to too high or low charge in specific cells.

9. A HSCB shall be installed in the high voltage connection to the energy storage system, if independent of the propulsion system as approved by SDOT.
10. HSCBs shall be installed in series with both the positive and negative terminals of the energy storage device.
11. Ground fault detection circuits shall be used to monitor the OESS for ground faults, including between energy storage cells.
12. The energy storage device terminal voltage may be lower than the normal operating range for the other car systems, permitting an energy storage device with fewer cells. The chopper would convert the energy storage device voltage to that needed by the auxiliary and propulsion systems.
13. Temperature controls and forced ventilation equipment shall be provided to control the energy storage device cell temperature to keep the energy storage device cells at the optimum temperature for capacity and long life.

9.6.3 Energy Storage Device

If batteries are used they shall be constructed using low maintenance Lithium Ion type, service proven railway or transit quality battery cells. Additional battery types may be proposed but are subjected to SDOT approval

If capacitors are use they shall be constructed using high current, high capacity, service proven railway or transit quality capacitors cells.

The energy storage device shall be installed in a temperature controlled ventilated enclosure outside the passenger compartment. Maintenance access shall be provided to service the devices.

The energy storage device compartment arrangement shall be large enough to accommodate energy storage devices from at least two independent suppliers.

9.6.4 Thermal Capacity

The continuous thermal rating of all OESS components shall exceed the rating that is necessary to operate with the normal duty cycle specified in Section 2, over the allowable range of overhead contact system voltage. All OESS components shall function as specified without damage under these conditions.

9.7 CDRL

The following design submittals are required:

9-1 One-line power distribution diagrams for all voltage levels

9-2 Format and schedule for current load integration report.

9-3 Current load integration report.

9-4 Grounding scheme report.

9-5 Pantograph design report

9-6 Alternatives to a high voltage shop switch

9-7 Shop switch description and drawings

9-8 Ground brushes description and drawings

9-9 Line filter description, including failure detection, and drawings

9-10 Auxiliary power supply design report

9-11 Fault management design report

9-12 Low voltage system design report

9-13 Low voltage power supply design report

9-14 Battery description, recommended charging processes, battery protection, emergency load calculations and assumptions, and mounting location

9-15 OESS design report

SECTION 10

PROPULSION SYSTEM AND CONTROL

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SECTION 10

PROPULSION SYSTEM AND CONTROL

10.1 General

Each streetcar motor truck shall be provided with a propulsion system functionally independent of, but coordinated with, all other propulsion systems in the vehicle. The propulsion systems may share the HSCB (see Section 9), but all other components shall be independent. Each propulsion system shall be able to operate independently of the other, including dynamic braking, in order to provide the capability of continued, but diminished, performance.

The propulsion system shall function with the energy storage system specified in Section 9.6. The energy storage system may be integrated into the propulsion system and may share control logic and power components as appropriate for the application.

The propulsion system shall include power modulation devices, traction motors, drive gear units, control logic, friction brake blending logic, wheel spin-slide correction, circuit protection devices, and all accessories necessary to meet the specified requirements of propulsion and dynamic braking.

The Contractor shall submit a schematic of the high voltage system for review by SDOT. (CDRL 10-1)

10.2 System Requirements

10.2.1 Propulsion System Configuration

Power modulation in both propulsion and dynamic braking shall be accomplished by microprocessor-controlled, IGBT (insulated-gate, bipolar-transistor) inverters.

For conventional bi-motor trucks, the motors shall be electrically connected in parallel or single axle drives (one inverter/motor per axle). For unconventional trucks or running gear, motors and drive gears shall be arranged to minimize un-sprung weight and tractive effort losses, reduce curve negotiation noise, optimize adhesion utilization, and reduce mechanical stress from the motor output, through the gear drive, to the wheel/rail interface.

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

The propulsion controls shall allow a vehicle to operate at any speed on a grade, including zero speed, and prevent reverse motion by propulsion control alone.

10.2.2 Drive Configuration

Drive configuration shall be one motor per one or two wheels, depending on the proposed drive arrangement. The traction motor shall drive its associated axle(s) through a gearing arrangement. The arrangement shall minimize unsprung weight on the driven axles and provide resilience to absorb the shocks resulting from running through special trackwork. All motors, gear units and couplings shall be interchangeable between motor trucks.

10.3 Equipment Thermal Capacities

10.3.1 Normal Duty

The continuous thermal rating of all propulsion system components shall exceed the rating that is necessary to operate with the normal duty cycle specified in Section 2, over the allowable range of overhead contact system voltage. All propulsion system components shall function as specified without damage under these conditions.

Rheostatic braking resistors shall be sized for the specified duty cycles, as though there were no regenerative braking, and the resistors must dissipate all braking energy.

The Contractor shall submit run time simulations, over the SDOT alignment, at AW3 load showing traction motor, IGBT and brake resistor duty cycles. (CDRL 10-2)

10.3.2 Abnormal Duty

The abnormal duty cycle shall be based on either the towing requirements or the normal duty cycle of Section 2, whichever is worse. If the normal duty cycle provides the worse case, all equipment shall be thermally rated as specified in Section 10.3.1, above.

If the towing requirements present the worse case, then the traction motor abnormal duty rating may be based on the temperature rises allowed for its actual insulation class.

The Contractor shall submit the selected abnormal duty cycle for approval. (CDRL 10-3)

10.3.3 Equipment Temperature Control

Equipment may be air or liquid cooled, except for motors, which shall be air-cooled only. Equipment cooling shall be provided on a per-truck or per-motor basis so that continued operation is possible in the event of cooling system failure.

Forced air cooling shall not use ambient air in any area of exposed voltage stress above 50 volts.

Liquid cooling systems shall be permanently sealed and shall not require preventive maintenance for the life of the equipment. The use of chlorofluorocarbons (CFCs) is prohibited.

10.4 Switching Line Transients

Switching line transients normally generated by the propulsion system shall be suppressed such that the instantaneous voltage complies with IEC 60850.

All vehicle-borne equipment shall withstand all vehicle and wayside generated transients without damage or reduction in life. Refer to Section 2.3.4.

10.5 Electromagnetic Interference

Electromagnetic interference (EMI) limits as specified in Section 2 shall not be exceeded as a result of propulsion system operation. In addition, the propulsion system shall be designed to operate in an environment of high ambient electrical noise. Such electrical noise could be self-generated, generated by other vehicle systems, and generated off-vehicle.

10.6 Performance Characteristics

The propulsion system shall provide train acceleration and deceleration rates as specified in Section 2. The Contractor shall provide tractive effort vs. speed curves for motoring and braking at the minimum, nominal, and maximum voltage conditions specified in Section 2. (CDRL 10-4)

10.6.1 Accuracy and Response Times

The propulsion system time response shall be sufficiently fast to:

- Provide the specified vehicle acceleration and deceleration rates, with accuracy, jerk rate, and mode change dead times as specified in Section 2.
- Provide the specified wheel spin and wheel slide correction performance

The specified accuracies and response times shall be independent of ambient temperatures within the range specified in Section 2, variations of the low voltage supply within the limits specified in Section 2, and variations in the wayside power supply voltages as specified in Section 2.

10.6.2 Friction Brake Control

Control of disc brakes may be provided by the propulsion system electronic control unit or a separate friction brake electronics control unit.

If the propulsion system logic includes the friction brake control logic, it shall function with the friction brake pressure control units to automatically apply braking effort when the required deceleration rates are not achieved by dynamic braking. This control signal shall meet the safety requirements of Section 2.

If the friction brakes are controlled by independent control logics, the propulsion system logic shall provide an accurate dynamic brake delivered signal per inverter to the brake control logic as specified in Section 12.5.

10.6.3 Dynamic Brake Capability

Dynamic braking effort shall be produced by the propulsion system as specified in Section 2.

The dynamic brake shall be combined regenerative and rheostatic and shall be continuously available from maximum vehicle speed down to a vehicle speed of 5 km/h or less. The dynamic brake control system shall continuously monitor line voltage on each inverter cycle, shall supply to the line the maximum amount of energy possible within the line voltage limits prescribed, and shall divert to the braking resistors only that generated energy in excess of the energy accepted by the line. Dynamic braking shall be available independent of the presence of line voltage.

10.6.4 Dynamic Brake Fault

Dynamic brake failure detection circuits shall be provided for each truck. Whenever dynamic brake is commanded, the circuit shall verify that dynamic braking effort at the correct level is produced. If it is not produced at the correct level, all residual dynamic brake effort shall be cut out and a dynamic brake fault shall be indicated for that truck. The dynamic brake feedback signal to the friction brake system shall be clamped at zero under dynamic brake failure conditions. Dynamic brake failure detection and associated interface circuits shall conform to the train safety design requirements specified in Section 2.

10.6.5 Direction Change

Direction change shall be provided by traction motor field rotation reversal. The inverter control shall respond to the direction control signals generated by the reverser switch in the cab. A change of direction shall be possible only when no-motion is detected and the tractive effort is zero. Correspondence between the control line command and motor rotation shall be monitored. In out-of-correspondence conditions, the friction brakes shall be applied and a roll back condition flagged.

10.6.6 Roll Back Protection

The propulsion system shall detect and prevent vehicle motion in a direction opposite to that selected by the cab when a propulsion mode is selected.

The roll back protection shall safely stop the vehicle within a distance of 400 mm or if the speed exceeds 1.5 km/h.

The roll back protection system shall be coordinated with the friction brake system.

10.6.7 Wireless Operation

The propulsion system shall include features to allow the vehicle to operate using power provided by the energy storage system specified in Section 9.6.

10.6.8 Cut-Out Control

Provisions shall be included for each powered truck of a vehicle to be independently isolated from the propulsion control signals and the catenary supply. This isolation will be referred to as "propulsion cut-out". With one truck cutout on a single vehicle, it shall be possible to operate the vehicle in either direction with no damaging effects over the whole alignment. If needed, a speed limit may be automatically applied when any truck is cut-out. Refer to Section 10.6.10, below. All other systems shall remain operational.

10.6.9 Wheel-Spin Slide Correction

A wheel spin-slide detection and correction circuit shall be provided as an integral part of the propulsion control system. The wheel spin-slide correction system shall meet the requirements of Section 2 and shall be coordinated with the friction brake slide control.

10.6.10 Overspeed Protection

The propulsion control system shall include overspeed protection which limits vehicle speed to set values by means of tractive effort and brake control. Speed information shall be derived from a source which is corrected for wheel wear.

The overspeed protection logic shall remove propulsion, and command a brake application when the vehicle speed exceeds the overspeed protection set point. Braking shall be maintained irretrievably to below the no-motion detection speed, after which control shall be restored by moving the Master Controller to the maximum service braking position.

The overspeed protection shall set the tractive effort to 0 kN at 70 km/h +2 km/h when all systems are normal. Full service brake shall be applied 2 km/h above this overspeed limit set point. An additional overspeed protection set point may be utilized when any propulsion or brake equipment has been cut-out or when a propulsion or brake system failure has been detected. See other Sections of this document. These additional overspeed levels shall be based on the thermal capacity of the remaining functional equipment, or operating rules as determined by SDOT, whichever is less.

10.6.11 Circuit Protection and Visual Annunciation

Circuits powered from the overhead contact system shall be protected as required by Section 9.

Control circuits shall be protected by low voltage circuit breakers.

Visual annunciation of all propulsion system faults, including cut out, dynamic brake failure, general faults, ventilation failure, and overheating shall be annunciated in the cab and may impose a reduced overspeed set point, as appropriate.

10.7 System Components

10.7.1 Traction Motors

AC traction motors shall have the following basic design features:

Motor Type:	Three phase, squirrel cage induction motor, with welded copper cage, and formed stator coils.
Ventilation:	Forced-ventilated or self-ventilated.
Duty:	Thermally rated in accordance with the duty cycles as defined in Sections 2 and 9.
Load Sharing:	The motor characteristics shall allow achievement of all performance requirements with wheel diameter differences of at least 0.6% for motors driven in parallel by the same inverter.
Motor Standards:	IEC 60349 or IEEE Standard 11, except as otherwise specified, and IEEE Standard 112 as applicable.
Insulation:	Motor insulation shall be IEC Standard 85, Class 200 insulation system or better. The motor stator coils shall be vacuum pressure impregnated in the complete stator frame assembly.
Enclosure:	Splash proof or totally enclosed.
Mounting:	Each traction motor shall be resiliently mounted, either directly to the truck frame or to both the truck frame and gear unit. Unsprung mass of the motor-gear unit assembly shall be kept to a minimum. Safety straps, tabs or hangers shall be provided as required to prevent damage in the event of motor or gear unit mount failure.
Shaft Coupling:	A splined, taper fit, flexible coupling or flexibly coupled Cardan shaft shall be provided between traction motor and gear unit shafts. The coupling design and motor-gear unit mounting arrangement shall minimize coupling dynamic angular displacement.
Design Speed:	The motor design maximum speed shall correspond to a vehicle speed of at least 80 km/h with any permissible condition of wheel wear. Based on this maximum vehicle speed, the IEC 60349 definition of "maximum speed" shall be used.
Bearings:	Grease lubricated, NFL, antifriction bearings shall be provided. Grease cavities shall be large enough to hold a five year supply of lubricant. Configurations which use gear lubricant for the traction motor bearing at the pinion end are acceptable. Bearings shall have an ANSI/AFBMA L10 rating life equivalent to 1,600,000 km of service, or greater. At least one insulated bearing per motor shall be used to avoid induced currents damaging the motor bearings.

Motor and Rotor Balance:	Motors shall be dynamically balanced to meet the requirements of NEMA MG 1-12.06 or VDI 2060. In addition to the NEMA requirements for the amplitude of vibration, the IEEE Standard 11-13.2.2 requirements for the velocity of vibration shall be met. In addition to NEMA requirements for the assembled machine, rotors shall be dynamically balanced to within a maximum unbalance of 0.007 Nm, even if a greater unbalance will satisfy the NEMA MG 1-12.06 requirements. Balancing shall be effected by using metal weights, welded in place, or by drilling the rotor core.
Noise:	Motor shall be free of objectionable windage and mechanical noises at all vehicle speeds and under all load conditions.
Markings:	Terminals, leads, and motor frames shall be clearly marked for positive identification.
Electrical Connections:	Motor connections to vehicle wiring shall be established through a motor terminal box and be subject to SDOT's approval. Leads shall be secured to avoid insulation chafing and shall be routed to accommodate all truck motions without interference or excess strain. All wires, connectors and related hardware shall be rated for the peak voltages and currents present. The grounding concept and the wiring between the inverter and traction motor shall minimize the generation of stray currents.

The Contractor shall provide traction motor outline drawings and insulation process information for SDOT review. (CDRL 10-5)

10.7.2 Gear Drive

Gear units shall have the following basic design features:

Each motored axle or wheel shall be driven by a gear/motor arrangement properly designed for the proposed application.

Gear units shall be equipped with anti-friction bearings throughout. Bearing design and selection shall require inspection or adjustment no more frequently than once every 400,000 km. Bearings shall have an ANSI/AFBMA L10 rating life equivalent to 1,600,000 km or more of service. External bearing shaft seals shall be the labyrinth type, with supplemental sliding contact seals, if necessary to keep high velocity splashed water from entering the gear units.

Gears shall be designed and applied to require inspection and adjustment no more frequently than once in every 400,000 km and have a life of at least 1,600,000 km.

The gear unit shall be oil lubricated and provided with sufficient baffles, dams, and passages to ensure an adequate flow of lubricant to all bearings and gears under all combinations of acceleration, speed, direction, load, and environment. The gear unit shall prevent infiltration of moisture into the lubricant from any and all sources and shall not require replenishment of oil at a rate in excess of one quart for every 160,000 km.

The gear unit shall have openings with removable plugs located with easy access for filling and draining. Plugs shall be of a type or be located to prevent damage by obstacles on the track and the resultant loss of lubricant. Plugs shall be secured by lock wires, lock tabs, or other approved means to prevent loosening in service.

The filler plug opening shall be arranged to provide an indication of oil level and also prevent overfilling. Drain plugs shall have magnetic particle collectors.

Removable and accessible oil-tight and airtight inspection covers shall be provided on the gear housing for visual inspection of the gears.

The Contractor shall provide a gear unit outline drawing and technical data on the gear unit for SDOT review. (CDRL 10-6)

10.7.3 Dynamic Brake Resistors

The dynamic brake resistors shall have sufficient capacity to provide full power dissipation during operation at maximum service braking over the specified profile and passenger loadings up to and including AW3, assuming no regeneration into the line.

Resistor grids shall be electrically isolated from their frames, and the frames electrically isolated from the vehicle body and heat shield with high temperature insulation. Provision shall be made for grid expansion to prevent warping. The resistor grids shall be convection ventilated and roof mounted. Screens shall be provided to protect resistors from overhead vandal 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.

The Contractor shall provide brake resistor drawings and technical data for SDOT review. (CDRL 10-7)

10.7.4 Contactors

The use of contactors for propulsion control shall be minimized to the greatest possible extent.

All propulsion system contactors shall be capable of safely interrupting the maximum possible load current in the event of a control malfunction. If in combination with the HSCB, contactors need not be rated to interrupt all fault level currents. The arrangement of arc chutes, blowout coils and venting, along with the contactor tip size, shall allow safe continued operation upon reset after a malfunction.

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.

10.7.5 Propulsion Line Filter

The line filter(s) shall conform to the requirements of Section 9.2.5.

10.7.6 Control Logic

The propulsion system 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 be provided with 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. The propulsion controls shall comply with the design requirements of Section 17.

The Contractor shall provide inverter layout drawings and technical data for SDOT review. (CDRL 10-8)

The Contractor shall provide a description of vehicle control logic functionality, interface with vehicle data bus and diagnostic features for SDOT review. (CDRL 10-9)

The Contractor shall provide an interface description between the vehicle control logic and the friction brake controls for SDOT review. (CDRL 10-10)

Independent control logic units and logic power supplies shall be provided for each truck such that one truck can function if the propulsion equipment for the other has failed.

All 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 or CAN. The bus shall be redundant, fast and reliable.

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 unit shall provide continuous monitoring of critical parameters, including motor currents, switching device currents, 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. The detection and response times shall permit detection and corrective action on a per unit basis before other protective devices, including the HSCB, react. The fault monitoring schemes and response performance shall be submitted for approval by SDOT. (CDRL 10-11) The control logic shall be part of a comprehensive diagnostic system as specified in Section 17.

10.8 CDRL

The following design submittals are required:

10-1 High voltage schematic

10-2 Run time simulations at AW3 load showing traction motor, IBGT and brake resistor duty cycles

10-3 Abnormal duty run time simulation showing traction motor, IBGT and brake resistor duty cycles

10-4 Traction system characteristics in motoring and braking for line voltages of 525V, 750V and 900V and from the energy storage system.

10-5 Traction motor outline drawing and insulation process information

10-6 Gear outline drawing and technical data

10-7 Brake resistor drawing and technical data

10-8 Inverter layout drawing and technical data

10-9 Description of vehicle control logic functionality, interface with vehicle data bus and diagnostic features

10-10 Interface description between vehicle control logic and friction brake controls

10-11 Fault monitoring schemes and response performance

SECTION 11

TRUCK ASSEMBLIES

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SECTION 11

TRUCK ASSEMBLIES

11.1 General

This Section specifies the design and functional requirements of the truck assemblies. The "trucks" are defined as all components from the rail to and including the first components rigidly fastened to the carbody. Gear boxes, motors, wiring, brake system components, and associated mounting brackets are physically part of the truck assemblies but are not included in this Section, except that any mechanical interface requiring welding or drilling on the truck frame shall be considered part of the truck.

The truck frames may be of either inboard or outboard bearing design.

The trucks shall be designed, and the truck frames manufactured, by a supplier(s) who has designed and manufactured the same trucks previously for the vehicle offered. Adaptations are limited to changes in dimensions, materials or procedures necessary to comply with this Specification. The trucks shall have operated in the same or more unfavorable climatic conditions over track meeting FRA Class 4 requirements, and at the same or higher maximum speed.

The trucks shall minimize resonant vibrations when in operation. Surface contact between truck components, except suspension stops, shall be made through service-proven, non-metallic materials to impede the transmission of vibration and noise.

The trucks shall be suitable for safe operation at all speeds specified in Section 2, and shall provide the specified ride quality over the entire range of speed and wheel wear noted herein.

11.2 Design Considerations

11.2.1 Service Life

The truck structure shall have a service life of 30 years minimum, without the need for structural repairs.

11.2.2 Wheel Base

Truck wheel base shall be as needed to meet the requirements of the Specification.

11.2.3 Interchangeability

Trucks shall be interchangeable among any vehicles furnished under this Contract, without modification.

11.2.4 Clearance Considerations

The complete truck assembly shall clear the car body and car body-mounted equipment by not less than 12 mm. All truck parts, except wheels and track brakes, shall clear the plane of the top-of-rails by not less than 50 mm. These clearance limits shall be met when full allowance is made for the most unfavorable combinations of:

- Wheel tread or flange wear
- Static and dynamic primary and secondary spring deflection

- Primary and secondary suspension failure
- Static and dynamic suspension stop deflection, including possible wear of the suspension stops to the condemning limit
- The full specified range and worst case combination of horizontal and vertical curves
- Any other possible movement of the trucks and associated parts including that caused by the maximum excursions of any truck-mounted parts

The Contractor shall submit drawings showing truck clearances under the above mentioned worst case conditions.

The design shall permit the removal of the motor trucks from under the vehicle in areas of minimum headroom. It shall not be necessary to raise the carbody more than the minimum distance required for the truck and traction motors to pass beneath the emergency tow bar in order to roll the trucks out from under the carbody.

11.3 Suspension System

11.3.1 General Requirements

Truck suspension shall be comprised of a primary and secondary suspension system. The carbody shall be supported on the secondary suspension.

The maximum change in vehicle floor height, due to vehicle loading changes from AW0 to AW3, shall be limited by the ride quality requirements, clearance requirements, and prevention of interference between the doors and wayside loading platforms during door opening. The Contractor shall submit a summary report as to how the selected suspension characteristics provide optimum performances in consideration of the above design requirements. This report shall address, at a minimum, how optimization of the following was achieved:

- Ride quality (see Section 2)
- Curve negotiability (horizontal, vertical and combined)
- Wheel load equalization
- Static and dynamic clearances
- Running stability

11.3.1.1 Load Leveling

A load leveling system may be proposed, but not required.

If proposed the system shall be incorporated into the suspension system of all trucks, and provide automatic regulation of floor height within specified tolerances, as approved by SDOT.

11.3.2 Primary Suspension

Primary suspension shall be by means of coil, elastomeric elements in compression, or a combination thereof. The vertical resonance frequency of the primary suspension system shall not exceed 12 Hz. The longitudinal spring rate shall be selected such that all the requirements of this Specification are met. The longitudinal spring rate shall permit the axles to align properly (absent squealing or hunting) in curves, but shall in no case exceed 1600 kg/mm per axle box.

11.3.3 Secondary Suspension

The carbody shall be supported by a secondary suspension system consisting of steel springs, air springs with height adjustment and pressure control devices, or other approved means, designed to resist those lateral forces expected in rail service. The springs shall be augmented by horizontal and vertical dampers, as necessary, to optimize ride quality. Longitudinal forces may be transmitted between the truck frame and carbody by the secondary suspension springs.

11.3.4 Dampers

Vertical and lateral dampers, if required, shall be of the hydraulic type and shall have a minimum service life of 10 years. The Contractor shall submit the service history of the proposed dampers.

11.3.5 Suspension Stops

Lateral and vertical suspension stops for both primary and secondary suspensions shall be provided with replaceable elastomeric cushions. Stops shall develop sufficient force to limit motion to within clearance requirements. Vertical suspension stops may be incorporated into the vertical dampers. The Contractor shall submit drawings and an explanation detailing how vertical and lateral movement of the carbody will be managed.

If air spring suspension and/or hydraulic devices are employed, a back-up suspension made of elastomeric springs or other approved means shall be provided to allow the train to continue operating at revenue service speed.

11.3.6 Wear Adjustment

Provision shall be made in the truck design for up to 50 mm of vertical mechanical adjustment of the primary or secondary suspension to compensate for maximum wheel wear and wear or settlement of other truck parts. The adjustments shall be accomplished with standard maintenance shop equipment, and shall not impair the operation of the truck. Adjustment at the extreme limits shall not cause the vehicle to exceed the specified dynamic envelope.

11.4 Truck Frame and Bolster

11.4.1 General Requirements

Truck frames and bolsters shall be of a service-proven design, fabricated either by welding or via castings.

There shall be no sliding surfaces involved in the method of retaining the journal bearings in their proper positions. The design of the truck shall allow compensation for the expected maximum level of creep or settlement of the primary and secondary suspension springs and wheel wear.

Threaded fasteners, adjustment points, and structurally-critical locations shall be accessible for inspection and work using conventional means and tools.

11.4.2 Connection

A positive mechanical connection shall be provided between the carbody and trucks, such that the trucks will be raised with the carbody without disengaging any part of the suspension system. These connections shall be detachable by conventional hand tools to permit de-trucking. The strength of the connection shall provide a factor of safety of not less than two times the yield strength of the material when lifting a fully assembled truck.

The ultimate strength of the truck-to-car body connection shall be sufficient to secure the entire truck to the carbody under conditions in which a horizontal force equal to three times the weight of a fully-assembled truck applied in any direction at any point on the truck, without separation of the truck and carbody. The ability of the truck-to-car body connection to sustain this load shall be independent of the presence of any vertical load. The horizontal load may be transmitted from the truck to the carbody through structural members, positive stops, or other rigid, mechanical safety devices.

The Contractor shall submit strength calculations demonstrating compliance to the above requirements.

11.4.3 Truck Frame and Bolster Strength

The truck frame and bolster shall be service proven. The Contractor shall submit previous design data, FEM/FEA, static and fatigue test reports of the proposed trucks to demonstrate that the trucks are capable of withstanding all the static and dynamic loads induced during the life of the car. The Contractor shall submit FEM/FEA and supplemental manual analyses, as required, to demonstrate compliance with the strength requirements.

The FEM/FEA shall, as a minimum, include the following:

- A structural diagram of the truck frames and bolsters (or carbody connections) showing all member locations, shapes, material and thickness. The methods of joining shall be completely defined, including AWS D1.1 weld classifications for fatigue for all welds.
- A table showing the engineering properties of each grade and temper of each material.
- Diagrams displaying external loads and supports applied to the truck frames and bolsters (or carbody connections).
- Color plots graphically showing results of stress calculations.
- A tabular summary of the results of calculations of stresses in all members. The locations where calculated stress levels equal or exceed 85% of the allowable stress criteria shall be shown in a separate table, along with the design or operating conditions (loads) which cause them.
- An analysis of all critical connections of the truck frame and bolster (or carbody connections) major structural elements under all specified loading conditions.
- A tabulation of the Contractor's proposed allowable static and fatigue stresses and applied fatigue stress ranges for the members that are fatigue critical.
- An identification of all critical welds.

Following summarizes the static and dynamic load conditions that the trucks must accommodate:

- Truck frame, bolster and all truck mounted components shall be capable of withstanding the maximum load variation imposed by the forces acting on the frame. The basis for determining maximum load variation shall include forces resulting from passenger load, track shock, motor torque, friction brake and track brake loads, and any possible combination of these forces when operating under all conditions of track meeting the minimum requirements of the FRA Class 4 “Track Safety Standards”,

per 49CFR Part 213, at speeds up to and including the maximum specified speed, for the specified life of the car.

- The static strength design condition for the truck frame and bolster shall be based on the requirements of the above paragraph and a design load 5 percent above AW3 carbody weight (= total AW3 weight – truck weights). Under these conditions (including 1.05 x AW3 carbody weight), vertical load shall not be less than the truck's share of the design load calculated at the truck bolster interface. Longitudinal load shall not be less than the maximum possible instantaneous braking effort with the wheels at full load and 40 percent adhesion. Lateral load shall not be less than that load which, when applied to the vertical center of gravity, will cause the vehicle to overturn. With the foregoing loads applied, the maximum stresses at any location in the truck frame and bolster shall not exceed 85 percent of the yield strength of the material.
- The fatigue design of the truck frame and bolster shall be based on the above conditions with a car at the AW2 passenger load level. The mean vertical load shall be the truck's share of the design load [(1.05) (AW2 carbody total – truck weights)]. For test purposes, actual vertical load shall be varied about the mean vertical load by ±25 percent. The lateral load shall be varied between 15 percent of the mean vertical load, directed towards one side of the truck, and 15 percent of the mean vertical load, directed towards the other side. The lateral and longitudinal loads shall act as if they were applied at the center of gravity of the carbody at full load with resulting vertical loading applied to the bolster. Propulsion and braking tractive effort loads shall vary between ±100 percent of their steady-state values; that is, as though the propulsion and friction brake systems were both outputting maximum braking torque with not less than 40 percent adhesion. Under these conditions, stresses shall not exceed fatigue allowables (given below) with an additional factor of safety of 1.5 on the mean stress, where the applied stress is at the fatigue limit for the materials.
- Fatigue allowables for truck materials shall be limited to published endurance stress values for smooth, flat, tension-tension specimens, and/or recent Contract test series with sufficient individual tests to establish the endurance stress value for 95 percent survival at the 84 percent confidence level.

In the event that the Contractor proposes trucks designed to other recognized standards, the Contractor shall submit detail design conditions, FEM/FEA analyses, test reports of the truck frame and bolster, and justification documents which demonstrate as to how the proposed trucks provide an equivalent level of structural and fatigue strength, and are safe over the entire life of the car.

11.5 Journal Bearings

Journal bearings shall be grease lubricated, tapered or spherical roller bearings with an L_{10} life probability of not less than 500,000 km at AW2 vehicle weight with the shock and impact loads typical of rail vehicle service. Bearings shall be service-proven for streetcar use. The Contractor shall submit bearing life calculation for approval.

11.6 Wheels

The truck shall use a resilient wheel with a steel center (hub). The tire shall be replaceable by bolted connections, and shall not require the pressing off any axle components. The wheel

assembly shall be SAB/Wabco V-type with noise dampeners, Bochum 84, or other approved design.

The wheel assembly shall also serve as the electrical interface for grounding the vehicle to the running rails for the return of propulsion and auxiliary current, and to shunt the signal system track circuits from rail-to-rail. Conductive paths with the capacity to conduct all specified currents shall be provided by no less than 3 external shunts, per wheel, between hub and tire.

11.7 Axles

The Contractor shall submit a load diagram and static and dynamic stress calculations for the axles which show, at a minimum, the maximum value of stresses to which the axles are expected to be subjected in service, and a prediction of the axle's fatigue life using the cumulative damage (or other approved) calculation method. The Contractor shall consider the effect of the bending loads induced by the presence of restraining rails in the axle bending fatigue stress calculations.

11.8 Wheel and Axle Assembly

The wheels, bearings, and ground brush ring shall be fitted to the axle by pressing or mounting. The fit tolerances and pressing forces shall be as recommended by the equipment manufacturers. The Contractor shall submit the press fitting procedure for all components pressed on the axle for approval.

11.9 Track Brake Support

The track brakes shall be supported from the journal bearing housings. The track-brake support arrangement shall maintain positive lateral alignment of the track brake with the running rail. Track brake forces shall be transmitted to the truck frame as near to the top-of-rail as practical to minimize the moment on the track brake unit.

11.10 Safety Bars

Safety bars shall be provided at the outboard ends of the trucks. They shall be mounted with a maximum clearance of 100 mm to top of the rail when all truck parts are new. Clearance shall not be less than 50 mm for the worst case combination of conditions specified in Section 11.2.4.

Safety bars shall be arranged and mounted for replacement with common hand tools.

11.11 Grounding Device

Each truck shall be provided with grounding devices meeting the requirements for electrical grounding specified in Section 9.

11.12 Wheel Lubrication System

A wheel lubrication system shall be provided for each wheel, as approved by SDOT. The lubrication system shall apply lubricant through constant contact with a solid block.

11.13 Truck Serial Number

Each truck shall be provided with a serial number plate located in a conspicuous place. The figures shall be not less than 20 mm in height.

11.14 CDRL

The following documents shall be submitted for approval:

11-1 Dimensioned structural drawings and material lists for the truck frame, including all brackets and mounting points for related components, such as brake equipment, dampers, radius rods, etc. Detail shall be sufficient to validate FEM/FEA analyses. Carbuilder shall also provide a detailed explanation of the fabrication process.

11-2 Calculations demonstrating carbody-to-truck connection strength

11-3 Service history of dampers, including manufacturer(s) and part number(s)

11-4 Drawings and documents showing truck clearances under worst case conditions

11-5 FEM/FEA and supplemental manual analyses

11-6 Supporting data for trucks, if designed to alternative standards

11-7 Journal bearing L10 life calculation

11-8 Strength calculation for axles

11-9 Press fitting procedures for wheels, gears, journal bearings and ground brushes

11-10 Analysis showing how the selected suspension characteristics provide optimum performance

11-11 Drawings and explanation showing how vertical and lateral movements of the carbody will be managed

SECTION 12

FRICTION BRAKE SYSTEM

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SECTION 12

FRICTION BRAKE SYSTEM

12.1 General

This section establishes the requirements for the vehicle friction brake system and control.

The friction brake system may be spring applied and hydraulically released, or hydraulically actuated. Friction braking shall be provided on each independent wheel and on each axle.

Within 180 days of NTP the Contractor shall prepare a friction brake system design report for SDOT review and approval. When data is requested in this Section for design review it shall be included in this report unless otherwise specified. (CDRL 12-1)

12.2 System Description

The friction disc brake system shall perform the following basic functions:

- Provide service and emergency braking in the event of dynamic brake failure
- Provide supplemental braking effort to the dynamic braking for car weights above AW3
- Provide emergency braking with the assistance of dynamic brakes, track brakes and sand
- Act as a parking brake system

In the event of a dynamic brake failure in a single traction system, the friction braking shall provide equivalent maximum braking effort, but may do so with a different distribution of braking effort among the wheels/axles.

12.3 Friction Brake Control Power Source

The friction brake control equipment shall use the vehicle low voltage DC power system as the power source. Refer to Section 2.3.2.

12.4 Friction Brake Electronic Control Units (ECU)

Friction Brake ECUs shall comply with the electronic design, network, software, and MDS requirements stated in Section 17.

12.5 Dynamic Brake Interface

A dynamic brake signal shall be utilized by the disc brake control logic system for each truck to reduce disc brake effort in response to the presence of dynamic braking on that truck.

If the disc brake control logic is within the propulsion system, the propulsion control ECU shall calculate the required disc braking effort. Reference Section 10.

12.6 Parking Brake

A spring-applied parking brake shall be provided for each wheel or axle. It must be possible to keep a fully loaded vehicle safely stopped at a 10% grade.

The parking brake control signal shall be configured to release the parking brakes when energized. A parking brake applied anywhere on a vehicle shall inhibit the propulsion and brake release indications.

In pressure-released systems, parking brakes shall be controlled by application and release of the service brakes.

12.7 Disc Brake Cutout

The disc brake system design shall include a method to release and cutout the disc brakes, allowing a vehicle to be moved in the event of failure.

12.8 Disc Brake - Propulsion System Interlock

The disc brake system shall be interlocked with the propulsion system such that propulsion is removed if any disc brake remains applied on any truck for more than 7 sec after the application of propulsion.

Complete disc brake release shall be possible at all vehicle speeds down to zero kph.

In hydraulic pressure-applied systems, the disc brake system shall be interlocked on a direct basis with propulsion control to prevent the application of propulsion in the event there is insufficient fluid available to complete an all-friction Emergency Brake stop from the maximum vehicle speed.

12.9 Thermal Capacity – Duty Cycle

The friction brake system shall have thermal capacity to provide for one all friction brake stop out of the maximum vehicle speed at the maximum vehicle load.

The friction brake system shall have the thermal capacity to provide continuous operation with a passenger loading at AW3 and a performance reduction in motoring due to the failure of one propulsion system/dynamic brake.

A reduced speed limit may be applied to prevent overloading the friction brakes as well as the still functional propulsion system.

12.10 Disc and Hub

All discs and hubs shall have thermal characteristics and strength to resist warping and cracking due to thermal stress resulting from the specified duty cycle.

The power truck discs supplied on the car shall a segmented design attached to a hub. The hub shall be pressed on the axle or may be attached to the gearbox output shaft, as approved by SDOT. (CDRL 12-2) The disc and hub together shall statically balance within 40 ozf-in (0.28 N-m).

All discs shall be vented with radial or circular ribs separating the two friction surfaces to provide sufficient cooling between stops. The ribs shall be arranged to avoid generation of pure tone noise.

Wear indication grooves shall be provided on both edges of each disc to indicate the minimum allowable disc thickness.

Brake discs shall be interchangeable among all power truck axles.

12.11 Calipers, Actuators, and Pads

Brake actuators shall be mounted to floating calipers designed to follow the disc regardless of lateral axle motion. The calipers shall also accommodate all other relative motions between the brake discs and the truck frame without binding, causing accelerated wear, or damage to truck or brake components.

Each disc shall be equipped with one hydraulic spring-applied pressure-released actuator, with an integral spring-applied parking brake actuation device. The brake actuator shall include an automatic slack adjustment feature, which shall compensate for brake pad wear as well as assure drag free running.

The brake pads and holders shall be designed for quick pad replacement without disassembly of the caliper unit. Brake pads shall be interchangeable between all axles.

The brake pad, caliper, and disc assembly shall not emit audible squeal, chatter, or other undesirable sounds.

12.12 Track Brake

Track brakes shall be applied during emergency braking and when commanded by the operator. Track brake applications during emergency stopping shall be interlocked with the no-motion detection circuitry and disabled below the no motion detection point.

The track brake system shall be effective at all speeds from maximum down to full stop over all conditions of curves and grades. Track brake force shall not be modulated by blending, load compensation, or other means.

Track brake control and logic may be provided by relays and contactors separate from the disc brake or propulsion control logic. Each truck's track brakes shall be controlled by a separate relay and contactor circuit, fed from a separate circuit breaker.

12.13 Sander System

Sand shall automatically be applied during emergency braking and during severe wheel spins or slides. Manual control from the operator’s cab shall also be possible.

Automatic sanding, resulting from a wheel slip or emergency brake application, shall be interlocked with the no-motion detection circuitry and disabled below the no motion detection point. Manual sanding shall be possible only if a vehicle direction is selected but shall not be interlocked with the no-motion detection point.

12.14 CDRL

The following design submittals are required:

12-1 Friction Brake System Design Report

12-2 Mounting of disc brake hub

SECTION 13

VEHICLE COMMUNICATIONS

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SECTION 13

VEHICLE COMMUNICATIONS

13.1 General

The on-board communication system includes the public address (PA), passenger emergency intercom (PEI), cab-to-cab intercom, passenger information, radio, video surveillance (CCTV), automatic passenger counting and train-to-wayside communication (TWC) systems.

The Contractor shall furnish all communication equipment specified below. In addition, radio chargers, or space for the future installation of train radios by SDOT shall be provided on the operator's console and in the cab electrical locker.

All communications and passenger information equipment shall be rated for continuous duty. Control and power circuits for all communications and passenger information equipment shall be isolated from the chassis and cabinets and shall be rated to pass the insulation tests specified in Section 15.2.

All communication equipment shall be powered from the low voltage dc system.

The communications system functions that require data transfer between cars, or components within a car, shall utilize an Ethernet Network, using a mesh topology, where a single point network failure shall not cause the system to fail.

The communication controls shall incorporate a Local Diagnostic and Test System (LDTS) that interfaces with the Central Diagnostic System (CDS) and portable test units (PTU), described in Section 17.

13.2 Audio Communications Functional Description

The communications system shall be configured to allow the following audio communications:

- From the operator to passengers inside and outside the train
- Among cabs in a vehicle, and the cabs of a vehicle being towed
- Between passengers inside the vehicle and the operator
- From the passenger information system to passengers inside and/or outside the train via pre-recorded announcement sequences and destination sign displays
- From the door system to passengers inside and/or outside the vehicle.

13.3 Public Address System

The public address system shall permit the operator and the passenger information system to make audio announcements to passengers inside or outside the vehicle. The door system shall also use the PA system for announcements and warnings.

Amplifier output levels, speaker impedances, and car wire sizes shall be selected such that the output volume is the same from each speaker.

Speaker size, quantities, and characteristics shall be selected to meet the performance requirements below. The frequency response of all audio circuits, from signal origin to output

signal at the speaker shall be 150 Hz to 10 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 door system shall use the automatic station announcement system to generate the door signal tones and announcements.

Operator initiated PA messages shall override passenger information system and door system messages.

All messages shall be intelligible and acoustically pleasing under all operating conditions.

Speech peaks shall be limited to approximately 5 dB above the average input level.

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.

The Contractor shall submit a Public Address Design Package (CDRL 13-1) for review and approval by SDOT.

13.3.1 Amplifiers

Each car shall be provided with a minimum of 1 PA amplifier per vehicle section, and shall have sufficient power to drive interior and exterior speakers at maximum levels, simultaneously, without audible distortion. The frequency response of power amplifiers below 100 Hz shall fall off at a rate of no more than 6 dB per octave. The PA amplifier shall use the communication network to receive data.

13.3.2 Automatic Volume Control

The PA system interior and exterior output levels shall be automatically adjusted in accordance with ambient noise levels prior to each announcement, regardless of origin. The range of automatic adjustment shall be a minimum of 10 dB. The maximum output level shall be at least 15 dB above typical worst case ambient noise levels for the interior when the vehicle is moving at maximum speed and at least 15dB for the exterior when the vehicle is stationary at a station selected by SDOT.

13.3.3 Cab Microphone

A rugged boom style, gooseneck, or console mounted, noise-cancelling, dynamic, microphone shall be provided in each cab, usable for all PA, cab-to-cab, and PEI modes.

The cab microphone preamplifier shall contain a compression circuit. Compression circuits shall be provided to maintain output regulation of +1, -0.5 dB, no load to full load, measured at the speaker terminals.

13.3.4 Interior Speakers

Interior speakers shall meet or exceed the following criteria:

- A minimum of one speaker for every 1800 mm of car length
- Arranged to eliminate feedback from any audio input source
- Provide an even, comfortable, sound distribution, and intelligible audio, at all seating locations, within 3 dB, under all vehicle operating conditions.
- Mounted in the ceiling to provide even coverage in each body section.

- Grilles shall be: flush mounted, finished to match the panel, perforated, removable for access to the speaker, and held in place with tamper-proof screws.

13.3.5 Exterior Speakers

Exterior speakers shall meet or exceed the following criteria:

- A minimum of four external speakers per vehicle, two per side.
- Impervious to environmental conditions as outlined in Section 2.2.
- Waterproof method of mounting the speakers and routing the speaker wires.
- The speaker locations shall not violate the vehicle's dynamic outline.
- Immune to the chemicals and detergents normally used during car washing, shall not interfere with nor damage mechanical car wash brushes, and shall be designed to withstand forces generated by these brushes.

13.4 Intercom System

The intercom system shall allow calls to be initiated from any cab, with or without an active console, or any passenger emergency intercom station in the vehicle.

The Contractor shall submit an Intercom Design Package (CDRL 13-2) for SDOT review and approval.

13.4.1 Cab-to-Cab Intercom

A cab-to-cab intercom call shall be annunciated in every cab, by means of a one-time call chime and an indicating light. The indicating lights shall stay on until the call is completed.

Provision shall be made for the connection of the cab-to-cab intercom system between vehicles during towing operations. A separate cable which attaches at either cab end through a weather-proof connector will be acceptable.

13.4.2 Passenger Emergency Intercom (PEI)

The passenger emergency intercom system shall allow communication between passengers in the vehicle and the operator. At least two units shall be installed in the vehicle, at locations determined by SDOT.

The system shall function as follows:

- Pressing the call request button at a PEI station shall cause each call request to enter a first-in, first-out queue in the PEI control system. A light on the PEI station shall illuminate, indicating acknowledgement of the call request.
- When the call request comes to the top of the queue, the operator is hailed via a tone and indicator lamp at the active cab console. The operator acknowledges the call by pressing an acknowledge button, which sets up a half duplex communication channel between the active cab and the PEI station. The operator may speak to the passenger when the microphone switch is pressed, and the passenger may speak to the operator when the switch is not pressed.
- Audio from the passenger is heard in the cab speaker. Audio from the operator is heard by the passenger via the speaker in the PEI station.

- When the conversation is finished, the operator terminates the call by pressing a button on the cab console and the active PEI station returns to an inactive state. If there are no more calls in the queue, the PEI session is terminated. Otherwise, the next call in the queue hails the operator in the same manner.
- If the operator activates other audio functions on the cab console, all PEI activities shall be placed on hold and the queue is maintained. The PEI indicator lamp on the cab console shall remain illuminated. The operator shall return to the PEI session by pressing a button on the cab console.
- Passenger emergency intercom stations (a minimum of two per car) shall be located in each wheelchair area so as to be easily accessible for wheelchair patron's use. The unit shall be flush mounted at a height of 1220 mm above the floor.

Audio from the passenger intercom shall be heard only in the active cab and at the active PEI station.

13.4.3 PEI stations

The passenger emergency intercom unit shall consist of a panel-mounted enclosure constructed from stainless steel, which shall enclose a loudspeaker, microphone, large pushbutton switch, an indicating light (which may be part of the pushbutton switch), and any necessary auxiliary components to make the system function. The units shall be of splash-proof, vandal-resistant construction. Electrical connections shall be by means of concealed multi-pin connectors.

The pushbutton shall be arranged to prevent unintended nuisance application during crowded conditions in the passenger area.

The microphone shall be Omni-directional, with external filters to resist background noise. The speaker shall be constructed of materials like the interior PA speakers, and shall have a power rating of at least 3W. The speaker and microphone shall be mounted behind perforations in the PEI unit front panel, as small as possible to provide adequate performance while reducing opportunities for vandalism.

The passenger emergency intercom unit shall be marked with engraved graphics, in English text and Braille, to identify the unit as an "Emergency Intercom" unit. The instructions shall read, "To Contact Driver Push Button Once", or approved similar language. A permanent label or decal shall be applied to the vehicle next to the passenger intercom unit to identify the vehicle and PEI station location.

13.5 Automatic Passenger Information System (APIS)

The vehicle shall include equipment for automated broadcast of pre-recorded audible and visual announcements of transit system information such as train location and destination as well as destination information to passengers on the wayside.

The control of all destination signs, audio announcements, and 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.

The Contractor shall submit an Automatic Passenger Information System Design Package (CDRL 13- 3) for review and approval by SDOT.

13.5.1 Functional Description

Announcements shall be triggered automatically by route selection, vehicle position, door openings and manually via the operator's console control. Vehicle position shall be based on GPS. A backup distance based system shall also be incorporated to correct or supplement GPS data when not available. Contractor shall submit details of the position determining system, accuracy, error detection and other parameters as required, for approval.

Audio announcements shall be broadcasted over the PA system, and corresponding visual announcements shall be displayed on the interior information signs. The message database structure shall include instructions to direct audio to the interior, exterior, or both speaker sets.

The system shall provide as a minimum the following passenger information:

- Station Arrival Information: Station identification may include station name, exit locations, and bus or train transfer information
- Next Stop Announcement: When leaving a station, the system shall broadcast next station and train destination information
- End of Line
- Destination/Route Description
- Public Service Announcements

13.5.2 User Programming, Message Formats

The system shall have enough capacity to store 50 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. Storage for audio messages shall assume at least 30 seconds per message. Text messages shall assume 100 characters each. Message capacity shall depend only on available memory. There shall be no inherent limitation built into the control software or algorithms. Message, station, and route 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 SDOT for review and approval.

All audio messages shall be recorded using an approved human voice and shall be submitted to SDOT for review and approval.

The PI system shall use a database structure to store all data. 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.

The updating, creation, deletion, uploading, and downloading of PI system information shall be intuitive, database structured, and shall be contained within 1 program; recording of audio messages can be performed using different software. The approach will be submitted to SDOT for approval.

A complete set of equipment for the recording and modification of the visual and audible messages, and routes shall be provided to SDOT. The system shall be comprised of standard

COTS equipment. This equipment shall include everything required to reprogram the on-board systems with new messages, routes, stations, etc.

13.5.3 Operator Controls

The operator shall be provided with a control panel which will allow:

- Initiating the system
- Entering temporary information such train ID, and operator ID
- Entering route ID
- Selecting specific messages
- Altering the normal message sequence, such as skipping stations
- Display of system status and other relevant information

The control panel shall include a keypad or similar input device with function specific keys. Entering commands via codes is prohibited. The panel shall include a display showing system states, entered information, system diagnostic and fault data, presently announced messages, and similar information. The display shall be a back-lit LCD or authorized alternative.

13.5.4 Initiation of Announcements

The system shall be initiated by the operator by entering a route ID number, which shall determine which message sequence and special features are to be used by the system. The present location of the vehicle in the route's station sequence may also be entered if vehicle location is not known at initiation.

Once initiated, the system shall be self-controlling via knowledge of train position, calculation of distance, door openings, and the route definitions stored in the system.

System initiation shall also establish the settings for the end destination signs in each cab, and all side destination signs in the vehicle.

When the cab is activated, the system shall initiate itself to the last route ID, or to a default setting if the last active ID is not present. The route ID shall be stored when the cab is keyed off.

13.5.5 Destination & Information Signs

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

All cars shall have a minimum of 4 interior and 4 exterior signs. The internally-viewed signs shall be installed in wall panels at approved locations, shall be interchangeable, and display 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 SDOT.

Visual display signs shall be either, single-line, dot-matrix LED or back-lit LCD displays, yellow or amber on black, capable of scrolling a message, as approved by SDOT. 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.

13.6 Radio

The Contractor shall provide space on the operator's desk for a radio and associated wiring and power. Details of the radio will be supplied during Design Review. The Contractor shall be responsible for installing and testing the radio.

The Contractor shall submit a Radio Design Package (CDRL 13-4) for review and approval by SDOT.

13.6.1 Radio Antenna

The radio antenna shall be mounted on the roof of the car near each radio transceiver. The antenna installation shall not exceed the dynamic envelope of the vehicle. The installation shall not interfere with nor damage mechanical car washer brushes and shall be designed to withstand forces generated by these brushes.

The antenna mounting method shall be waterproof without the use of sealers or caulk, and shall allow replacement of the antenna without cutting or damaging the antenna cabling.

13.6.2 Radio Power Supply

A transformer isolated, industrial grade, dc-to-dc power converter shall be provided for each set of radio equipment. The output voltage shall be as recommended by the radio manufacturer. The converter shall be powered from the vehicle's low voltage dc power supply, via a dedicated circuit breaker. The converter shall include input voltage transient suppression rated for no less than 150 J, and shall include output over-voltage protection and current limiting.

The converter may be used to power other cab equipment which may require the same dc voltage as the radio, in which case the power rating of the converter shall be selected accordingly.

The converter shall be rated for continuous output current 25% greater than the maximum load current drawn by the radio transceiver and all other relevant loads.

13.7 Automatic Passenger Counting (APC)

13.7.1 General

The Contractor shall provide each vehicle with an automatic passenger counting (APC) system. The system shall count the passengers that enter and exit the vehicle at each station and the passenger count, location, time, and car number shall be recorded in an onboard database for downloading via PTU and remote processing of the data at a later time. The system shall automatically transfer the data to the wayside via the same wireless LAN transceiver that is used to transmit MDS information to the wayside when the vehicle is in the maintenance shop and yard.

The system shall count passengers with an accuracy of 96% or better for each round trip on the SDOT Streetcar system. Sufficient memory shall be provided to hold 45 days of data, assuming 20 round trips a day.

The Contractor shall provide the necessary operating software for the vehicle and wayside. Software needed for PTUs to maintain the system, download data and software necessary to analyze the data in the SDOT offices shall be provided. The Contractor shall provide SDOT with any necessary licenses to use the software for the design life of the vehicles.

The system shall consist of the equipment described below. The equipment shall conform to the material and design requirements of this Specification.

The Contractor shall submit an Automatic Passenger Counting Design Package (CDRL 13-5) for SDOT review and approval.

13.7.2 APC Doorway Equipment

Each doorway of the vehicle shall be equipped with multiple sensors and associated logic unit to sense passengers entering and exiting the vehicle. The combination of sensors and logic shall properly detect and indicate the correct passenger count regardless of whether single or multiple persons are simultaneously entering or exiting a doorway, or any simultaneous or overlapping combination of entering and exiting persons.

The APC doorway equipment shall function accurately regardless of the size of the passenger, from small child to large adult.

The APC doorway equipment shall not interfere with operation of the doors.

The APC doorway equipment shall receive an indication from the door system when the doors are open. Direct connections shall be used to communicate between APC sensors and the APC doorway logic unit. Communication between the APC doorway logic units and the central logic unit shall be by a network that conforms to the requirements of Section 17.

13.7.3 APC Logic Unit

An APC Logic Unit shall be provided to collect, process, and store the data from the APC doorway equipment. It shall determine the position of the vehicle by a combination of the following:

- Starting location information from the automatic announcement system
- It shall receive distance traveled information from the propulsion system
- No-motion as indicated by the vehicle no-motion logic
- Door open status signals from the door control system

Logic shall process the door and location data and store it in non-volatile memory with sufficient capacity to comply with the requirements of Section 13.8.1.

The APC Logic Unit shall contain logic to detect system faults and receive fault data from the APC doorway equipment. A fault log shall be maintained in the APC Logic Unit. In addition to functioning with the PTU to permit manipulation and display of this data, the system shall communicate with the MDS to transmit the fault log and permit manipulation and display of the passenger count data via the MDS specified in Section 17.

13.7.4 Remote Access

The equipment shall be provided with the appropriate interfaces and software to use the vehicle wireless communications equipment to automatically transfer APC data to the wayside. Refer to Section 13.11 and 17.4.

13.8 Communication System Integration with MDS

The Contractor is encouraged to combine and integrate the APIS, Communications, and MDS hardware, wiring, and functions to the maximum extent possible.

13.9 CCTV

Each vehicle shall be equipped with a Closed Circuit Television (CCTV) consisting of at least 4 exterior and 6 interior 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 any component within the system to fail.

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

CCTV Workstation software shall be provided for installation on standard PC computers for uploading operating parameters (such as sampling rates), downloading of video data from the DVR, verification of authenticity, image and video enhancement, and similar processes. The interface connections to the DVR shall be Ethernet, arranged as a TCP/IP network connection. The software shall be Web-browser based, and compatible with common internet Web browsers, such as Internet Explorer or Mozilla Firefox.

The Contractor shall submit a CCTV Design Package (CDRL 13-6) to SDOT for review and approval.

The camera locations, coverage, capacity, control software and arrangement shall be subject to approval by SDOT (include in CDRL 13-6).

13.9.1 Exterior Side View CCTV

In place of side-view mirrors for the train operator, CCTV shall enable the Operator to supervise the loading and unloading of passengers at all doorways of the car when the doors are open, and to verify that the doors on the train are clear of passengers. Each exterior side of each cab shall be equipped with color CCTV cameras wired to a pair of color, LCD-based display screens located within the cab. The side-view CCTV shall be active only in the active cab.

If an exterior camera fails the system shall, indicate a failure to the operator, and shall automatically switch to the camera on the opposite cab.

13.9.1.1 Side View Camera

Cameras shall be placed above the cab side windows to provide a clear view of the side of a train. Cameras shall be enclosed in heated, waterproof enclosures.

13.9.1.2 Cab Display

Color LCD monitors shall be placed on each side of the cab console or corner posts, connected to the camera for the matching side. Displays shall be backlit for night-time use and shrouded to prevent wash-out during bright conditions. Display screens shall be a minimum of 8 in (200 mm), diagonally, with pushbutton controls for contrast and brightness.

13.9.2 Interior Surveillance CCTV

Each vehicle shall be equipped with enough interior color surveillance cameras mounted to provide complete coverage of all passenger areas, 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 SDOT 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.

13.9.3 CCTV and Side View Cameras

Each camera shall record audio and video, having a minimum resolution of 1.3 megapixels (1280×1024), 16.7 million colors, and use MPEG-4/MJPEG compression, or better, such as H.264 compression. The camera shall have a maximum frame rate of 30 fps using MPEG-4, 15 fps using MJPEG compression. The frame rate and bandwidth for each camera shall be controllable, using the CCTV controller.

13.9.4 Digital Video Recorder

The following events shall trigger high resolution recording at a reduce frame rate, the resolution and frame rate shall be software adjustable, using a PTU.

- Distress Signal over the radio
- EB application
- Passenger Intercom activity
- Passenger Emergency Door release
- Incident Alarm switch activation

The DVR shall be able to store 21 days worth of CCTV recorded video, computed using a minimum: 20 hrs per day, image resolution 1280×1024, 15 fps, and high quality compression; the DVR shall have a minimum capacity of 1 TB.

The used/unused capacity of the DVR shall be viewable, using the CCTV controller, by maintenance personnel and the operator.

The recording method shall include an approved authentication process to detect any alteration of the data after recording.

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

13.10 GPS

A GPS system shall be provided for use by the PI and MDS system, and other systems on the vehicle that require position and time information. The GPS shall provide the vehicle 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 other vehicle antenna's to avoid interference.

The Contractor shall submit a GPS Design Package (CDRL 13-7) to SDOT for review and approval.

13.11 WIFI IP Router

The Contractor 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

Refer to Sections 17.4 and 17.5.

The Contractor shall submit a WIFI Router Design Package (CDRL 13-8) to SDOT for review and approval.

13.12 Automatic Vehicle Locator (AVL)

The Automatic Vehicle Locator system is an advanced, real-time traveler information management and display system, comprised of wayside displays, windows-based message creation and control software, and World Wide Web vehicle location for public use (such as NextBus). The system shall provide accurate vehicle location, updated at regular intervals, using GPS. The system shall use the vehicle GPS, or shall have a dedicated GPS system. The GPS antenna shall mount on the roof, or other location, optimized for satellite access. The antenna location shall be coordinated with other vehicle antenna's to avoid interference.

The Contractor shall submit an Automatic Vehicle Locator Design Package (CDRL 13-9) to SDOT for review and approval.

13.13 Traffic Light Priority

The vehicle shall include a traffic control system conforming to SDOT design guidelines. The system will be used to prioritize side and front traffic lights, 4 per car. The system shall be compatible with the existing SDOT system.

The Contractor shall submit a Traffic Light Priority Design Package (CDRL 13-10) to SDOT for review and approval.

13.14 Train-to-Wayside Communication System (TWC)

The Contractor shall furnish and install the car borne portion of the train-to-wayside communication system in accordance with requirements described in this Section. The car borne TWC equipment shall function with the existing wayside TWC equipment, and shall provide bi-directional data transfer, backwards compatible with a Philips Vetag TWC system.

The Contractor shall submit a TWC Design Package (CDRL 13-11) to SDOT for review and approval.

13.14.1 System Description

Each end of the vehicle shall be equipped with car borne components of the TWC system to transmit digital information from the Streetcar to the wayside, or wayside to Streetcar, at certain points along the route. Fixed wayside loop antennas placed in the trackway send out an interrogation signal several times a second. When a car passes over the loop antenna and an activated car borne TWC transponder receives the interrogation signal it shall transmit a message to the wayside in the form of high-speed serial digital data.

Vehicle TWC equipment provided by the Contractor shall be completely compatible with the existing wayside equipment and shall be subject to SDOT's approval.

13.14.2 Functional Requirements (Philips Vetag TWC system)

Vehicle TWC equipment shall be installed to provide for the accurate, secure transmission of a 19-bit data message to/from wayside loop antennas. Transponders shall transmit when properly located over the loop and polled by the wayside interrogator. However, the format of the data message to be transmitted shall be a function of vehicle status. The Streetcar shall be configured to provide the TWC system with inputs representing active cab status and end-of-train status.

The TWC system shall transmit the following information from the vehicle to the wayside:

- Train Number
- Route Number
- Car Number
- Stationary Preempt/Activation
- Switch Call (Left or Right)
- Active Cab (on for active cab)
- End-of-train
- Wireless or On Wire operation

The TWC system shall transmit the following information from the wayside to the vehicle:

- Start of wireless segment
- End of wireless segment

Additional TWC transmission requirements will be covered during system design.

Car number (to be transmitted by inactive cabs) shall be encoded via jumpers inside the cab control panel. The exact assignment of bits, including start/stop bit will be furnished to the Contractor by SDOT after contract award.

13.14.3 Carborne Equipment

Each car set of TWC equipment to be furnished and installed shall consist of:

- Two transponder assemblies (one per end)
- Two cab control panels (one per end)
- Interconnection cables and hardware to mount and connect transponders and cab control panels.

All carborne TWC equipment shall be identical in all cabs. The TWC system shall function from the low voltage power supply with the voltage range and conditions specified in Section 2. A dedicated circuit breaker shall be provided in the circuit breaker panel of each cab.

13.14.3.1 Cab Control Panel and Interconnect Wiring

The cab control panel shall include a unit of four pushbutton switches and a unit of four ten-position thumbwheel switches. The pushbuttons shall be back lighted when the transponder for the active cab is over a wayside loop and is being interrogated.

The following inputs to the cab control panel shall be provided:

- Battery positive, through a dedicated circuit breaker
- Negative Return
- Cab active signal
- Wireless operation
- End-of-train signal

All inputs shall be brought to a terminal board mounted under the console in an appropriate location near the cab control panel, and connect to the cab control panel via a multi-conductor cable and quick disconnect connector.

13.14.3.2 Transponder Assembly

Each transponder shall be mounted under the vehicle on the centerline of the carbody, so as to minimize offset on curves, and approximately one m from the end of the car. The mounting bracket shall be suitable for the operating environment and shall include any vibration dampening features necessary for a long-term integrity of the system. A multiple conductor cable suitable for exposed use in an undercar environment shall be provided to connect the transponder to the bulkhead connector. A waterproof quarter-turn bayonet electrical connector shall be provided on the cable. The other end of the cable shall enter the transponder through a watertight, strain-relief bushing.

The transponder shall:

- Receive a 100 KHz interrogation signal via the ferrite antenna to activate the transponder and cause it to transmit a data message via the same antenna.
- Activate the lights in the console panel switches when an interrogation signal is received to indicate that the transponder is located over a wayside loop.
- Transmit the 19-bit data message that is indicated by the cab control panel to the wayside interrogator.

13.15 CDRL

The following design submittals are required, each design submittal shall include:

- Vehicle integration drawings
- Functional descriptions
- Mechanic specifications
- Mechanical assembly drawings with weights, dimensions, and parts lists
- Electrical specifications
- Software design description
- Software flow diagrams

- Circuit schematics
- Electrical schematic drawings for each device, assembly, and Installation drawings.

Design Submittals:

13-1 Public Address Design Package

13-2 Intercom Design Package

13-3 Automatic Passenger Information System Design Package

13-4 Radio Design Package

13-5 Automatic Passenger Counting Design Package

13-6 CCTV Design Package

13-7 GPS Design Package

13-8 WIFI Router Design Package

13-9 Automatic Vehicle Locator Design Package

13-10 Traffic Light Priority Design Package

13-11 TWC design package

END OF SECTION

SECTION 14

INTERIOR AND EXTERIOR APPOINTMENTS

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SECTION 14

INTERIOR AND EXTERIOR APPOINTMENTS

14.1 General

This section describes interior and exterior finishing, including insulation, floor covering, seats, windows, liners, and other such features and appurtenances.

14.2 Interior Finishing and Accessories

The vehicle interior shall be finished with high durability, low maintenance materials. All surfaces shall be free from tooling marks, gaps, distortions, and other visible defects. All surfaces shall be rigid and supported to prevent sagging, drumming, and vibration.

All materials used in the interior of the vehicle shall conform to the flame, smoke, and toxicity requirements of Section 16.

Color shall extend all the way through all materials except for FRP and melamine, where specified.

Interior linings shall be mechanically fastened to their supporting surfaces. The mounting shall be designed to accommodate the dynamics of vehicle movement without transmitting stress to the liners. Interior linings shall be designed to have a minimum 25 mm radius cove at intersecting adjacent surfaces. Alternatives which bond the interior panel to the exterior wall as a unitized replaceable assembly will be considered.

All exposed stainless steel except for floor covering shall be given an approved brushed finish. Grain direction shall be arranged to be consistent with the decorative scheme.

Walls shall have a graffiti resistance rating of “one”, per APTA Transit Security Guidelines Manual, Section 21. The ceiling shall have a rating of “two”.

The vehicle interior shall be free of sharp corners or edges by design, and as a result of poor workmanship. Gaps between apparatus that are not absolutely rigid shall be wide enough to prevent injury when the apparatus moves, or rigid spacers shall be provided to prevent the gap from closing.

The articulation section flooring, walls, and other moving components shall move without audible noise under all conditions. All gaps between articulation section wall and ceiling panels shall be designed and sized to prevent injury. Gaps in the articulation portion of the passenger compartment shall not increase or decrease in width, so as to be hazardous to persons, under any conditions.

14.2.1 Acoustical Insulation

A vibration and sound damping material shall be applied to inner surfaces of all areas of the structural shell, including sub-floor pans, ends, roof, and side frames, and one side of air duct splitters (if used). It shall be resistant to dilute acids, alkalis, greases, gasolines, aliphatic oils, vermin and shall comply with the Flammability and Smoke Emission requirements in Section 16.

Alternatives which provide insulation between interior panels and the exterior wall as a unitized replaceable assembly will be considered.

14.2.2 Thermal Insulation

The vehicle shall be insulated to insure that the thermal requirements of Section 7 are met.

Fiberglass insulation shall be manufactured from long, textile-type glass fibers drawn from a calcium borosilicate mixture to an average diameter of nine microns. Insulation shall be bonded together with a thermosetting phenolic resin which shall not exceed 6% by weight. The fiberglass shall not mold, rot, or sustain vermin. It shall not corrode any metals or settle as a result of car vibration. It shall not have an odor or be capable of absorbing odors. It shall be capable of performing to a high temperature limit of 230^{o}C.

The roof, sides, and ends of the cars, including the inside faces of posts and structural members, shall be insulated with fiberglass which shall fill the entire volume of the available cavity. The density of the fiberglass insulation shall be selected by the Contractor consistent with the estimated carbody transmission heat gain given in Section 7. The roof insulation shall be retained by stainless steel wires or strips. Side and end wall insulation may be retained by spears or other approved method, provided steps are taken to ensure that sharp, pointed ends will not be a hazard to personnel or maintenance equipment.

The floor shall be insulated with two layers of equal thickness of fiberglass separated by a vapor barrier. This insulation shall be placed in the structural floor between the transverse floor beams and shall fill the entire volume of the available cavity. Floor insulation shall be compatible with the material used at the affected locations in the car structure. The density of the fiberglass insulation shall be selected by the Contractor consistent with the estimated carbody transmission heat gain given in Section 7.

Alternatives which provide insulation between interior panels and the exterior wall as a unitized replaceable assembly will be considered.

14.2.3 Urethane Foam

The use of urethane foam insulation is prohibited anywhere in the construction of the car. See Section 16 for other prohibited materials.

14.2.4 Floor Covering

The floor covering, and its accessories, shall provide a durable, watertight, textured covering for the floor panels and other car structures. The floor covering shall comply with the material and Flammability and Smoke Emission requirements in Section 16. The material shall be water and chemical resistant.

Floor covering shall be securely bonded to the floor structure with a water proof thermosetting adhesive.

The floor covering shall have a static coefficient of friction of not less than 0.5 if measured in accordance with ASTM D 2047, using leather and rubber shoe materials. Leather shoe material shall be in accordance with Federal Specification KK-L-165C. Rubber shoe material shall be in accordance with ASTM Method D 1630.

Each step shall be provided with a safety nosing running the full width of the step and which contrasts visually from the stair tread and riser covering by 70%, as determined by the following formula:

$$\text{Contrast (\%)} = [(B1-B2)/B1]*100$$

Where:

B1 = Light reflectance value of brighter area

B2 = Light reflectance value of darker area

Floor covering at exposed removable floor access panels and at the edge of the articulation section shall be peripherally trimmed with stainless steel or aluminum molding.

Contractor shall propose the material manufacturer and model. Actual flooring color and pattern will be determined by SDOT during the design review process.

14.2.5 Windows

All windows shall be of the single-glazed, fixed-type, laminated, tempered safety glass tested in accordance with ANSI Z26.1 or approved equivalent standard. Glazing shall be mounted directly to the car structure by bonding or with neoprene glazing strips.

Glazing strips, if used, shall be laced from the outside of the vehicle. The ends of the glazing strip shall be joined together by the hot vulcanization process or a gluing process approved by SDOT to form an endless glazing strip.

The side and door windows in the passenger section shall be have a minimum thickness of 6.5 mm.

All side and door windows shall be heat rejecting glass with a Solar Heat Gain Coefficient (SHGC) of no greater than 0.4, and a visible light transmission of no less than 0.75. Lower light transmission may be considered if SHGC values of less than 0.4 can be attained. All glass treatments must be permanent, within the glass and/or in the center membrane. Surface films are not permitted. SHGC and light transmission performance shall be as defined by the National Fenestration Rating Council or as approved by SDOT.

The cab windshield shall be laminated tempered safety glass, have a minimum thickness of 8 mm, and tested in accordance with ANSI Z26.1 or approved equivalent standard. The windshield shall also provide solar heat blocking features with the highest SHGC rating consistent with federal visibility requirements.

The windshield shall be designed and installed to minimize external glare as well as reflections from inside the vehicle when the vehicle is operated at night with the passenger interior lighting in use.

The upper portion of the windshield may cover the end destination sign.

All glass products shall be readily available in the U.S. from U.S. suppliers, in the sizes and thicknesses provided on the delivered vehicle.

14.2.6 Passenger Seats

Passenger seats shall be heavy duty transit-grade seats with removable cushion inserts. All visible structural materials shall be brushed stainless steel. Non-visible internal structures may be steel or stainless steel. Seat designs with formed synthetic frames, such as FRP or thermoplastics may be considered but flammability and smoke properties must comply with Section 16 requirements.

Seating arrangement shall be, as approved by SDOT and shall be predominantly transverse (knee-to-back, three abreast, 2+1 seating). Longitudinal seats may be permitted. Seating on opposite sides of the vehicle shall be separated by an aisle of 635 mm minimum width.

The minimum total seat depth measured from the seat's forward edge to the forward surface of the seat back shall be 400 mm. Minimum seat spacing shall be 735 mm. Minimum seat back-to-back of seat ahead shall be 650 mm. The seat individual width shall be 430 mm to 480 mm.

Passenger seats shall be designed using recognized ergonomic and human factors principles to provide a safe and comfortable ride for the short distance local patronage anticipated for the streetcar. Materials shall be consistent with the intended use and performance requirements, with special consideration for passenger safety, comfort, durability, maintainability and shall comply with the Flammability and Smoke Emission requirements in Section 16.

Replacement of seats shall be easily accomplished through removal and reinstallation of no more than six mounting bolts per seat. Mounting bolts shall be hidden by inconspicuous snap-in covers where exposed to passenger view.

14.2.6.1 Design Criteria

Seat construction and its attachments to the car structure shall conform to 49CFR 571.222 or APTA SS-C&C-016-99, Rev. 1.

Seating color and fabric will be determined by SDOT during the design review process.

14.2.7 Mobility Impaired Accommodations

Accessibility to the vehicles for mobility impaired persons confined to wheelchairs shall be provided through at least one door on each side of the vehicle. Two wheelchair spaces shall be provided in each vehicle. The spaces shall be designed to locate the wheelchair longitudinally (end facing) in the vehicle. Each wheelchair accommodation space shall provide for a minimum clear floor space of 1220 mm by 760 mm. Seat arrangement and stanchion placement shall provide for a minimum of 815 mm wheelchair passage width and allowance for turning movements between the accessible door and designated wheelchair locations. Each wheelchair space shall be provided with at least one horizontal handrail conforming to the section below and positioned 685 mm above the floor. In addition each wheelchair space shall include a means whereby the wheelchair user may activate the passenger stop request.

The wheelchair area may be either normally used by standees or provided with passenger seats which flip-up to allow space for the wheelchairs.

14.2.8 Stanchions, Handrails and Windscreens

Windscreens shall be provided at each passenger door location to define the boarding area and prevent drafts of external air from annoying passengers near the door and outside of the boarding area. Windscreens shall be transparent above the lower side window edge level.

Vertical stanchions shall be provided within 750 mm of any standing AW3 passenger position. Stanchions connecting the top of the seat back or the horizontal seat back rail to the ceiling, or vertical hand holds, shall be provided in the interior standing areas where no other passenger stabilization aid is available. Vertical stanchions shall not be placed in the boarding area between windscreens. Stanchion spacing and placement shall be submitted for approval. Each wheelchair space shall be provided with at least one horizontal handrail positioned 685 mm above the floor.

All stanchions and grab rails shall withstand applied loads of 1300 N in any direction without permanent deformation and without transient deformation that would pinch or injure. All stanchions and grab rails shall be smooth and free of sharp edges. All mounting fasteners shall be tamper resistant.

All stanchions and grab rails shall have a diameter of 32 to 38 mm and comply with the latest FTA interpretation of the Americans with Disabilities Act (36 CFR 1192 and 49 CFR 27, 37 and 38).

14.2.9 Keys and Locks

Three different types of keys shall be provided for access to various car equipment or controls. The three types are:

- Master Controller Key: Shall operate the master controller key switch, as described in Section 5, and provide access to the cab via the cab door. The master controller key shall be a seven-pin tumbler tubular key cut to a code assigned to SDOT.
- Crew Key: Shall permit operator access to cab breaker panels, exterior forward door manual release, all overhead access panels, access panels to under-seat equipment containing items requiring operator access, and shall be used to operate the door crew switch.
- Maintenance Key: Shall allow maintenance personnel to open all other access panels and shall be used for side skirt removal.

14.2.10 Provisions for Communication Equipment

Section 13 defines communication and fare collection equipment which shall be accommodated in the design of the vehicle interior. Typical equipment includes:

- Passenger Intercoms
- Information Signs
- Passenger Stop Request
- PA speakers
- Security Cameras
- Fare Collection Equipment
- Passenger Counting Equipment

The Contractor shall provide mounting space, brackets, wiring, connectors, and related components for all identified equipment. Such equipment shall be installed and tested by the Contractor, where specified.

14.3 Exterior Finishing and Accessories

14.3.1 Painting

All exterior surfaces of the vehicle structure shall be painted in accordance with the requirements of Section 16. All paint materials shall be submitted for approval. All painting materials shall be repairable by SDOT, using materials which conform to local, state, and federal regulations, and readily available and stocked in the U.S. from U.S. paint manufacturers.

Paint color schemes, including underfloor and trucks, shall be as defined by SDOT.

14.3.2 Roof Surface

All roof surfaces on which a person can walk shall be treated with anti-skid paints, as approved by SDOT.

14.3.3 Exterior Mirror

Replaced by exterior side-view CCTV. Refer to Section 13.9.1.

14.3.4 Skirts

Removable side skirts shall be provided between and outboard of the trucks, if car structure does not cover these areas. Skirts shall not be load bearing members and shall be removable with common hand tools or crew key. The skirts shall form a uniform lower edge with the bottom of the carbody in the low floor areas. Skirts may be modified in the truck areas to accommodate turning.

14.4 Cab Appointments

14.4.1 Cab Partition and Door

The operator's cab shall be segregated from the passenger spaces with a partition the full width and height of the vehicle interior. The partition shall include a cab door.

The enclosure shall be designed so that the operator's forward view, and views to the side monitors, are not obstructed.

The cab partition shall be a panel constructed from rigid, durable, integrally colored, mar-resistant material. The door opening and the door panel shall be framed in stainless steel, or other approved material. The door panel material shall be of the same material as the cab partition.

The cab door shall slide into the cab, either to the left or right.

The door shall be able to be locked from the passenger side by the standard crew, and from the inside by a manual lever. The latch shall include emergency egress provisions such that the door can be opened from the inside without first unlocking.

The door shall not rattle in either the latched (open) or locked (closed) positions.

The door shall have an openable and lockable window of laminated, tinted glass and shall include a grille in the lower portion for ventilation. Provisions shall be included to control reflected light from the passenger section lighting. The bottom of the door shall be provided with a stainless steel kick plate, 200 mm high, on the inside and the outside.

All latches and locks shall be heavy duty and made of white bronze or stainless steel. All other door hardware shall be stainless steel.

14.4.2 Operator's Seat

The operator area of each cab shall be equipped with an operator's seat located on the vehicle's longitudinal centerline.

The seat shall be a Recaro Ergo Mk II, or approved equal, with these options:

- FR treated foam
- Liquicell
- Arm-rest
- Air compressor, selected for the vehicle's low voltage dc system

The seat and back cushion shall be upholstered with transportation grade anti-microbial fabric, as approved by SDOT.

14.4.3 Sunscreens

Adjustable sunscreens shall be provided to aid the operator for all external light conditions, including simultaneous front and side sunlight. Each screen, its material, its mounting, and its adjustment provisions shall be service-proven in a transit application of similar nature considering factors such as window size and arrangement, operator position, color, and light blockage ratio. The sunscreen material shall not neutralize the color of traffic control signals.

14.4.4 Interior Mirror

One or more interior mirrors shall be provided in the cab. The mirrors shall be located and adjustable to provide the operator with a view of the passenger compartment. The mirror shall be of distortion free glass installed in an edge covering frame. The mirror reflecting area shall be at least 360 cm^2.

14.4.5 Fire Extinguisher

A 4.5 kg capacity fire extinguisher with a minimum rating of 4-A:30-B:C, marine type, shall be located in each operator's cab. The fire extinguisher shall be listed by Underwriters Laboratory and shall be provided with a marine type mounting bracket.

The fire extinguisher shall be clearly marked and accessible to the operator

14.5 Graphics

Graphics shall be provided throughout the vehicle to provide passengers and operating personnel information regarding operation of the vehicle. All decals shall be in both English and Spanish.

All controls and devices intended for operating personnel use shall be clearly labeled with text. All equipment intended for passenger use, however infrequent, shall be labeled both with text and graphical figures or icons in full compliance with ADA standards.

ADA compliant graphics shall designate priority seating for persons with disabilities. ADA compliant graphics shall indicate designated areas for wheelchair or mobility aid accommodation.

The car number shall be clearly displayed to aid operating personnel and passengers in reporting car locations or incidents. On the interior, the car number shall be displayed inside each vehicle body section. On the exterior, the car number shall be displayed on both vehicle ends above the windshield, the side of the vehicle, and on the roof at each end.

Safety warnings and advisories shall be provided at doors, at the articulation sections, and at any access points to hazardous equipment. Identifications and instructions shall be provided for all passenger interactive devices such as door push buttons, stop request buttons, and passenger emergency call boxes.

All equipment boxes shall be labeled with safety warnings for High Voltage, as appropriate.

All text and graphic layouts shall be submitted by the Contractor for approval by SDOT. A listing of typical signage presently used by SDOT is presented in the table below. Signage for this vehicle will be similar, but as defined by SDOT after NTP.

Description	Location
Priority Seating (Handicapped)	Centered above w/c location on light panels
Passengers Not Permitted Forward Of Yellow Line	Centered on bulkhead
Priority Seating (Elderly)	Interior, street/curbside above (front longitudinal seats)
Plate-Emergency Exit (Window)	On all emergency windows
Plate-Emergency Exit (Seat)	On all emergency window location
Push For Stop (Horizontal)	On light panel, center of window above tape
Fire Extinguisher	Fire extinguisher compartment
Push Tape For Stop (Vertical)	On post caps
No Smoking/Eating/Radio (International)	Centered on bulkhead
Watch Your Step	Centered on all steps and door ways
Open Doors Manually	Next to manual door operation
Open Emergency Door	Interior, over emergency door handle
Push Tape (Horizontal)	Interior, at wheelchair location
Caution-In Stepwell	On rear doors above stand clear decals
International Wheelchair	Per ADA requirements
Don't Forget Your Bike	At doorway
This Streetcar May Be Equipped With Audio Visual Recorders	Centered on bulkhead
4 inch vehicle numbers Helvetica medium type style. (Scotchcal decal material 3m3659-12 or approved equal)	On street side of vehicle above driver's window. On curbside of vehicle entrance door. On rear curbside & street side a/c panel. Street side rear engine door.
3 inch vehicle numbers Helvetica medium type style (Scotchcal decal material 3m3650 or approved equal)	On bulkhead within 2 inches of the ceiling (interior)
36 inch black vehicle numbers (roof) Helvetica medium type style (Scotchcal decal material 3m3650 or approved equal)	Centered between each carline and along the axis of the vehicle.

Description	Location
Electrical component locations specific to each electrical compartment	All interior and exterior electrical compartments

14.5.1 Routes, Schedules, and Advertising

Provisions for installing route maps, schedules, advertising, and similar material that is changed periodically shall be provided in the vehicle. Locations for such material shall be defined by SDOT during interior design reviews, but typically will be on cab or interior walls.

The material will be in sheet form, up to 2.3 mm thick, and shall be mounted in frames or similar fixtures provided by the Contractor. Actual sheet sizes shall be defined by SDOT but may range from 300 mm square up to 600 mm square.

Frame materials, retention methods, colors, and related features shall be as approved by SDOT.

14.6 CDRL

The following design submittals are required:

14-1 Interior and exterior color scheme, finishing, general appearance and seating arrangement

14-2 Paint and paint process

14-3 Acoustic insulation design report

14-4 Thermal insulation design report

14-5 Floor covering design report

14-6 Windows design report

14-7 Passenger seat design report

14-8 Mobility impaired accommodations

14-9 Stanchions, handrails, and windscreens

14-10 Key and unlock report and samples

14-11 Skirts material and latching mechanism (Section 14.3.4)

14-12 Graphics including car number (Section 14.5)

SECTION 15

TESTING

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SECTION 15

TESTING

15.1 General

The vehicle and all its components shall be tested to verify compliance with all specified design, performance, reliability, and maintainability requirements.

The tests included in this Section shall be performed on any equipment specifically designed for this Contract. If this vehicle or any of its equipment is being supplied as an already existing design, these tests may have been performed for other customers by the Contractor. Evidence of satisfactory completion of these tests, as determined by SDOT, may be sufficient to meet the requirements of this Section, unless design or material changes have been made to the items under test, unless the items are produced in a different facility, or unless the requirements are different. Reports of such equivalent testing shall not be dated earlier than 5 years before NTP of this contract with SDOT. Certain tests, however, must be performed regardless of any prior testing.

All tests described in this Section shall be performed as indicated unless specifically waived by SDOT. All tests shall be performed on production components without modification or special preparation.

SDOT may, at its option, witness all tests. At least 30 days prior to each test, the Contractor shall notify SDOT in writing of the date, time, and location the test will be performed.

Material test requirements may also appear in Section 16. Other test requirements may appear in other sections of these Technical Specifications.

15.1.1 Test Classifications

The required tests are categorized as follows:

- **Design Qualification Tests** shall be conducted to demonstrate compliance with design requirements at operating and environmental extremes. These tests shall be performed on selected production components, systems, and completed cars, at the highest level of assembly that will allow demonstration of design compliance. Design conformance tests are limited to the number of units needed to demonstrate design compliance, typically one or two. These test requirements are described in Sections 15.3, 15.4, and 15.5, and include both performance and operational tests.
- **Production Conformance Tests** shall be conducted to demonstrate that each unit produced operates within specified limits and is in compliance with the requirements of these Technical Specifications. Production conformance test requirements may vary from an inspection and functional demonstration for a simple component to full static tests of a vehicle. These tests are routinely performed at ambient conditions unless a specific environmental or operating limit is necessary to demonstrate acceptable operation. Conformance tests are routinely performed on each component, system, or vehicle in the order. These tests are described in Sections 15.6 and 15.7.

- **Vehicle Acceptance Tests** shall be conducted to demonstrate that each fully assembled vehicle is ready for revenue service, both functionally and aesthetically. The acceptance and post-delivery tests are described in Section 15.8.

15.1.2 Master Test Plan

Within 180 days after NTP, the Contractor shall submit to SDOT for review and approval a Master Test Plan (MTP) covering all tests required by this Section and elsewhere in these Technical Specifications. The MTP shall include a proposed schedule and location for each test.

15.1.3 Test Procedures and Reports

The Contractor shall prepare a detailed test procedure for each test described in the MTP, and for any other tests conducted by the Contractor in connection with its own Quality Assurance program. Each test procedure shall be submitted to SDOT for review and approval. Test procedures shall identify all specification sections relevant to the system or component under test, including those sections from which the test acceptance criteria were derived. The Contractor shall submit, as part of each test procedure, forms to be used to record data accumulated in that test. Such forms shall also contain a step-by-step format for data reduction, formulae used in deriving the format, criteria for acceptability, and justification for the criteria set forth.

Each detailed test procedure shall be submitted to SDOT in advance of the initial conduct of a planned test so as to provide at least 30 working days to review and approve the procedure. No testing shall occur, and no results shall be considered valid, until approval of the test procedures by SDOT.

Test reports shall be provided which follow the format of the test procedure to the extent possible. Test reports of conformance tests which are performed on all cars or all components shall be included in the appropriate Car History Book. The report shall include a description of the test, all raw data collected in the test, all data reduction forms, and a summary of the results.

15.2 Insulation Testing

When an insulation test is required to be performed in Sections 15.4, 15.5, 15.6, 15.7 and 15.8 it shall be conducted per the requirements stated IEEE Std 16-2004 part 5.9.

The integrity of electrical insulation shall be confirmed where specified below by performing insulation resistance tests and high potential tests on individual devices and apparatus, and then on the completed vehicle, as approved by SDOT.

15.3 Component Design Qualification Tests

The following design conformance tests shall be performed as indicated.

15.3.1 Flammability and Smoke Emission

All materials supplied for this car shall be tested to the Flammability and Smoke Emission requirements of Section 16.

15.3.2 Fire Performance

15.3.2.1 Floor Assembly Testing Requirements

The Contractor shall test the floor assembly (structural) in accordance with ASTM E 119, as stated above, to demonstrate a 30 minute endurance rating. The section of the floor to be tested, test procedure, test facility, and test results shall be subject to SDOT review and approval, and approved prior to the Contractor's procurement of any flooring material necessary for vehicle production.

The test criteria shall be as specified in NFPA 130-2010 section 8.5.1.

15.3.2.2 Roof Assembly Testing Requirements

The Contractor shall test the roof assembly in accordance with ASTM E 119, to demonstrate a 15 minute endurance rating. The test procedure, test facility, and test results shall be subject to SDOT review and approval, and approved prior to the Contractor's procurement of any roofing material necessary for vehicle production.

The test criteria shall be as specified in NFPA 130-2010 section 8.5.1.

15.3.3 AC Traction Motors

The ac traction motor shall be given a "type" test in accordance with IEC Publication 60349. The determination of the characteristics and efficiency of the traction motor shall be in accordance with a mutually acceptable method from IEC 60349 and IEEE Standard 112, adapted to include testing at minimum frequency, base speed, maximum slip-limited speed, and maximum speed.

15.3.4 AC Auxiliary Motors

One motor of each type of ac auxiliary motor shall be given an IEC Publication 60349 or IEEE Standard 112 "type" test, including a heat run, by the manufacturer, to demonstrate its capabilities and power rating. Each model shall be tested at its continuous rating.

15.3.5 Traction Gear Unit

The traction gear unit shall be subjected to a 100 hour test, and shall be mounted with torque load simulation. Alternatively, 100 hour test data and gear tooth contact verification data, previously run on identical gear units, may be submitted for review and approval by SDOT. The test shall subject the units to conditions that are, in general, 20% more severe than would occur under the most extreme operating conditions (i.e., power increased by 20%). Torque load shall include the effects of locked-in torque if a mono-motor design is used, and of dynamic braking.

The test shall be started with the unit at a temperature from 15^{o}C to 32^{o}C. A fan or other device may be provided so that in-service air flow conditions are simulated. The temperature rise measured in the oil sump shall not exceed the gear oil supplier's recommendations for maximum temperature consistent with the life between oil changes, as stated in the Contractor's maintenance manuals. The direction of rotation shall be reversed every successive 5 hrs until the 100 hr test is completed. Noise and vibration tests shall also be performed to verify the requirements of Section 2.

After completion of the test, the gear unit shall be disassembled and all parts examined. Gear tooth mesh and tooth pattern shall be checked and recorded before and after the test. The test

report shall include test records of running time, oil temperatures, and vibration and sound level readings taken at such intervals as required to verify compliance with this Specification.

15.3.6 Auxiliary Power Supply

The auxiliary power supply design qualification tests shall be performed on a production unit, based on the "Type Test" requirements of IEC 61287-1. These tests shall include all aspects of the following for the design requirements, environmental ranges, and supply voltages given in Sections 2 and 9 and as listed herein:

- All output and control requirements
- Performance and capacity requirements
- Combined system test demonstrating the capability to start up all ac loads, especially the HVAC compressors, under the worst case loading scenario possible, not including load failures
- Fault detection and annunciation requirements
- Insulation, isolation, and transient rejection requirements
- Heat run, designed to test the system for the worst case heat loadings for:
    - Maximum rated output current at the lowest operational input voltage
    - Lightest possible load, at the highest operational input voltage
- Noise measurements shall be made sufficient to demonstrate compliance with Section 2.

15.3.7 Low Voltage Power Supply and Battery Charger

Low voltage power supply and battery charger qualification tests shall be run on a production unit, based on the "Type Test" requirements of IEC 61287-1. The design conformance tests shall include the following:

- A continuous heat run of the unit at rated input voltage and rated output voltage and current. The heat run shall be of sufficient duration to allow all critical elements to stabilize in temperature. Temperature rises over ambient shall be within Contractor's limits as set forth in the test plan.
- The unit under test shall be run for one hour at an input voltage at the upper limit of the specified operating range, and at rated output current and voltage.
- The unit shall be run for one hour at an input voltage at the lower limit of the specified input range for which rated output voltage and current is to be delivered, at rated output voltage and current.
- The unit, when connected to its rated load, shall be cycled **OFF** and **ON** by interruption of the source voltage supply external to the unit under test. Rate of cycling shall be approximately one second on, one half second off, and shall continue for 2 minutes.
- The unit shall be started into an open circuit five times in succession.
- The unit shall be started into a short circuit five times in succession.

- The unit shall be started while connected into an overload at 120% of rating. The overload shall then be removed and the unit shall automatically provide rated output voltage.
- Noise measurements shall be made sufficient to demonstrate compliance with Section 2.
- At operating points representing the full range of conditions for delivery of rated output voltage and for routine current limit operation, output voltage and output voltage waveforms shall be monitored by an oscilloscope to determine compliance with the specified regulation and levels of ripple.

15.3.8 Truck Frame

The truck frame shall be given a static load test and a fatigue endurance test. The Contractor is responsible for selecting test loads and conditions that will develop a high level of confidence in the adequacy of the truck design.

The purpose of the static load test is to verify that the maximum allowable static stresses selected by the Contractor are not exceeded under the maximum expected static loads. The truck and bolster shall be loaded twice, with complete release of the load between applications. Strain gauges shall be re-zeroed after the first load application and the offset from zero recorded and reported. All required data shall be taken during both load applications. The methods and points of test load application and reaction shall simulate as closely as possible the actual loading conditions to which the truck will be subjected in service. The vertical test load shall be the truck's share of completed vehicle plus an AW4 passenger load minus the weight of the truck. The lateral load shall be 15% of the vertical component. The longitudinal load shall be the maximum possible instantaneous braking effort (friction and dynamic plus track brake) and 50% adhesion at the wheels at AW4 load. The lateral and longitudinal loads shall act as if they were applied at the center of gravity of the completed vehicle plus an AW4 passenger load. Accessory loads, such as brake units, track brakes, and traction motors, shall represent maximum steady state conditions; for example, maximum motor torque and brake unit weight, and maximum brake unit reaction and motor weight. All loads shall be applied to produce the worst stress conditions on the truck. Refer to Section 11 for additional test requirements.

To demonstrate that the truck has adequate fatigue strength under dynamic loading, the truck frame and bolster shall be subjected to not less than two million cycles of dynamic loading. The mean vertical load shall be the truck's share of completed vehicle plus an AW2 passenger load minus the weight of the truck, and the applied vertical load shall vary about the mean vertical load plus and minus 25%. The lateral load shall vary between 15% of the mean vertical load acting towards one side of the truck and 15% of the mean vertical load acting towards the other side. The longitudinal load shall vary between 15% of the mean vertical load acting towards one end of the truck and 20% of the mean vertical load acting towards the lateral and longitudinal loads shall act as if they were applied at the center of gravity of the carbody at the AW2 load, with resulting vertical loading applied to the bolster. Accessory loads shall vary between plus and minus 100% of their maximum steady state values: motor under maximum braking torque and brake unit tractive effort under maximum service brake application with not less than 50% adhesion and maximum track brake tractive effort reaction. The phasing of the loads shall be selected by the Contractor and shall be such as to produce the worst case stresses at critical locations. Refer to Section 11 for additional test requirements.

Alternatively, for trucks which have prior vehicle service history, the Contractor may submit existing "type" test data for approval by SDOT.

15.3.9 Carshell Structural Tests

15.3.9.1 General

The first carshell shall be tested by the Contractor to show that the critical portions of the car body structure comply with this specification. The tests shall not begin until the stress analyses have been approved.

The test shell shall be structurally complete, consisting of both shell halves with the articulation joint installed, but excluding such items as exterior and interior trim, windows, doors (except those used in the vertical load test), seats, lights, interior linings, insulation, or other parts that would obscure any structural member from view or that would interfere with the performance of the test. Equipment shall be simulated by equivalent weights at their respective locations. All structural tests shall be conducted on the same specimen.

15.3.9.2 Vertical Load Test

The car body specimen, supported on trucks, or a simulation thereof, shall be subjected to a vertical load test. A test load equal to the complete, ready-to-run car body weight (complete car minus trucks) plus a subsequent AW3 passenger load shall be applied to the specimen. The latter passenger load shall be applied in three approximately equal increments, resulting in a total of four vertical load increments. One of these increments shall be equivalent to a ready-to-run car body weight plus a passenger load of AW2. The test load may be applied by means of weights or jacks, but shall be distributed in proportion to the distribution of weight in the finished car. The specimen shall be unloaded in the increments that it was loaded, in reverse order.

During the vertical load test, a measurement of carbody vertical deflection shall be made on the car body shell with each test load applied.

All side doors on one side of the car shall be installed. The doors shall be complete with operators, thresholds, and all sealing and weatherstripping. All door equipment shall be production equipment installed in accordance with production drawings and procedures. At each increment of test load, the doors shall be opened and closed electrically by means of the operators. The opening and closing time of each door leaf shall be measured and recorded electrically. Failure to operate at the prescribed speed or any indication of binding shall require corrective action to be taken by the Contractor to the car structure or the door arrangement, or both. The vertical load test must then be repeated in its entirety.

15.3.9.3 Compression Load Test

The ability of the carbody structure to resist the compression loads specified in Section 3 shall be tested.

During the compression test, the car shell shall be supported on trucks or a simulation thereof to allow longitudinal movement.

The force of the testing machine shall be applied by hydraulic power and the force measured by a means independent of those producing the force. The compression test load shall be applied by means of a controlled hydraulic ram. Cushioning means, such as lead sheets, shall be provided to assure uniform bearing. The test load shall be applied horizontally on the car longitudinal centerline. No allowance shall be made for camber of the body. The load shall be applied in increments of 25, 50, 75, 87.5, and 100% of full load. The load shall be reduced to not more than 2% of full load after each step. Strain gauge and deflection readings shall be

taken at each load increment and at each relaxation of load. The ram shall be supported at the car end but shall remain free to move longitudinally with respect to the car end.

The test load shall be applied to the anticlimber, or an equivalent location determined by the SDOT in the event that no anticlimber is provided. This load shall be distributed over an area not to exceed 150 mm in height by 300 mm in width.

15.3.10 Traction Inverter

The traction inverter design qualification tests shall be performed on a production unit, based on the "Type Test" requirements of IEC 61287-1. These tests shall include all aspects of the following for the design requirements, environmental ranges, and supply voltages given in Sections 2 and 9.

15.3.11 On-Board Energy Storage System

The on-board energy storage design qualification tests shall be performed on a production unit, based on the "Type Test" requirements of IEC 61287-1. These tests shall include all aspects of the following for the design requirements, environmental ranges, and supply voltages given in Sections 2 and 9.

15.4 System Design Qualification Tests

The following system design conformance tests shall be performed by the Contractor, or under its direction, to demonstrate conformance to the requirements of this Specification.

15.4.1 Combined Propulsion and Energy Storage System Test

A laboratory test shall be conducted on one set of propulsion equipment, including motors, power conditioning, energy storage system (if provided), protection devices, logic, controls, and master controller, using a dynamometer which simulates vehicle inertia by means of flywheels or programming of a motor-generator, and which simulates train resistance by means of a motor-generator. The physical layout of car components and cabling for this test shall simulate actual car conditions except for the traction motors which might have to be at slightly different location. This test is for the purpose of demonstrating that the propulsion and energy storage equipment functions properly and meets all requirements of Sections 2, 9 and 10 prior to installation on the vehicle.

15.4.2 Friction Brake System

The complete friction brake system and all components shall be given a design conformance test on a dynamometer to confirm braking capability, thermal capacity, response, and wear rates. These tests may be included with the propulsion system laboratory tests. Testing shall include hot and cold retardation, wet and dry retardation, actuation energy storage, and control response.

15.4.3 Door and Bridgeplate System

Door, door operator, bridgeplate, bridgeplate operator, control, and sensitive edge design conformance tests shall include an accelerated life test of 1.5 million cycles for one complete set of door equipment and 250,000 cycles for the bridgeplate equipment. The door and bridgeplate equipment shall be assembled as a unit for the test. The test fixture used shall accurately represent the actual carbody and installation.

15.4.4 Unitized HVAC System

One self-contained HVAC unit of each type, complete with all controls, shall be given a test by the air conditioner manufacturer to confirm compliance with the requirements of Section 7. Testing shall also include a watertightness test as described in Section 15.5.16, a noise test, and power consumption measurements.

Test setup shall be according to the latest revision of ANSI/ASHRAE Standard 37. The test shall verify the capacity and functioning of heating, ventilating, cooling, and reheat, according to an approved temperature control schedule. The instrumentation accuracy and tolerances shall comply with Standard 37 requirements. All data required by Standard 37 shall be recorded using an appropriate data acquisition system.

The following tests shall be included in the procedure:

- Temperature control test to verify all temperature control schedule switching points on rising and falling temperatures.
- Refrigerant charge determination.
- Cooling capacity at design conditions specified in Section 7 (two methods, as required by ANSI/ASHRAE Standard 37).
- Functional test at maximum operating conditions with a unit ambient temperature of 40^{o}C. Equipment shall operate in full cooling mode without malfunction, shutdown, or modulation for at least one (1) hour.
- Demonstration of capacity modulation, if provided, at a unit ambient temperature up to 46^{o}C, and high pressure protection functions at a unit ambient temperature above 46^{o}C.
- Minimum full cool/low ambient and partial cool/low ambient, as determined by the temperature control schedule. System shall be tested for two (2) hours for each condition. Equipment shall function normally with no icing of the evaporator coils.
- Condensate carryover test at 27^{o}C DB/24^{o}C WB for at least four (4) hours. There shall be no condensate water anywhere within the unit (except drain pan) and supply air ducts.
- Heating capacity verification.
- Abnormal heating conditions tests with restricted air flow and without air to verify over temperature protection function.
- Back-up over temperature protective device test.

At the completion of the test, samples of the refrigerant and compressor crankcase oil shall be taken and analyzed for contaminants by an approved laboratory. Test results shall conform to the requirements of ARI Standard 700, except that moisture level of up to 30 mg/kg is allowed and the high boiling residue requirement is not applicable.

15.5 Vehicle Design Qualification Tests

15.5.1 General

Vehicle qualification tests shall be performed on the first car to establish that the overall car design meets the requirements of these Technical Specifications. These tests shall include both running tests demonstrating compliance with propulsion and braking performance, including

energy storage requirements, in Section 2, and other tests demonstrating compliance with other requirements in these Technical Specifications for a fully assembled car.

All of the tests shall be performed on SDOT's track or facilities unless otherwise approved by SDOT. The Contractor shall select, with SDOT's concurrence, a suitable test segment and determine where each test will start.

Locations shall be such that the opposite direction test run shall be run over the same portion of the alignment. The start location for each test shall be marked.

As a minimum, two runs in each direction shall be made for each running test. This series of tests shall be used to determine the equipment settings and calibrations for the car acceptance program. After the successful completion of the car level design conformance test program, the car used in the test shall be restored to its original configuration and retested with the complete car acceptance program instrumentation package.

The relationship between torque and the passenger load state, and brake cylinder pressure vs. passenger load state, shall be developed for a continuous range of passenger loadings from empty to fully loaded, and referenced to evaluate the acceptance testing of all other cars, which may then be tested without load during acceptance testing.

A plot of brake cylinder pressure vs. the "apparent" tractive effort produced (tractive effort plus the effects of train resistance, for a selected average speed) shall be constructed. All pertinent data from each test at each loading shall be represented on a single graph. All recorded data shall be corrected for voltage and grade as part of the Contractor's test report.

Test reports shall be forwarded to, and become the property of, the SDOT. All strip chart and recordings taken during the vehicle level design conformance testing shall become the property of SDOT.

If the car or apparatus fails to satisfy the specified performance and design criteria, the car, with the necessary adjustments, shall be redesigned and retested at the Contractor's expense. If modifications are necessary, they shall be effected on a fleetwide basis.

15.5.2 Instrumentation

For these tests, each car shall be instrumented with a Contractor furnished multi-channel data acquisition system which shall produce a permanent test record (both electronically and hard copy). The Contractor shall supply all recorders, sensors, transducers, pickups, equipment racks, test wiring termination panels, calibration equipment, wiring, and inverters to operate this instrumentation using the car low voltage power system supply. Internal combustion engines driving a generator or use of the car inverter power will not be permitted.

A proof of the calibration of all instruments, traceable to a master at the national standards organization of the applicable country, shall be submitted to SDOT for approval, prior to testing.

The equipment shall function over the low voltage power system voltage range described in Section 2. Isolation amplifiers and voltage dividers shall be provided as part of the instrumentation package to isolate the inside car instrumentation wiring and equipment from high voltages; no exposed terminals with potential differences greater than 50 V will be permitted.

The data acquisition system shall be capable of interfacing with all major systems through a serial bus. Wherever possible, applicable signals needed to verify vehicle performance shall be obtained from the serial interface with the equipment in question instead of hardwiring to obtain the desired signals.

The Contractor shall as part of the vehicle design process ensure that serial connectors are provided on all individual systems. Test wiring termination panels shall include test jacks and switching for each channel to permit calibration signals to be injected into each recorder channel without requiring wiring or connectors to be disconnected and shall be arranged so that calibration signals cannot be fed back into the monitored equipment. All equipment used must be calibrated.

The accuracy and response of the instrumentation shall be sufficient to determine compliance with the Specification and design criteria.

For each test, the following channel assignments shall be permanently recorded simultaneously, as specified:

- Acceleration (positive and negative). The signal shall be provided by an independent accelerometer (acceleration/deceleration rates calculated by the propulsion and/or friction brake system will not be considered acceptable for this requirement)
- Traction motor current/torque or effort (each truck)
- Spin slide system operation (each truck)
- Brake cylinder pressure (each truck)
- Brake disc temperature on one motor truck axle using thermocouples embedded in the brake pads.
- Catenary voltage
- Total catenary current drawn by each car
- Speed
- Propulsion and braking trainline command signals (or multiplexed to a single analog channel)
- Auxiliary inverter voltage and frequency outputs
- Energy storage system voltage and charge level (percentage of charge)
- Energy storage system current
- An independent time base with one second time intervals
- Such channels as the Contractor feels necessary to record the voltage transients of Section 10.
- Five spare analog and 10 spare digital channels for additional signals which may be requested by SDOT.

15.5.3 Propulsion Tests

The first series of tests shall be run at AW0, and a second series of tests shall be run at AW2. Performance requirements shall be as noted in Sections 2 and 10 for test conditions described below. Braking shall be monitored during all propulsion tests. As a minimum, the following tests are required:

- Acceleration rates and balancing speed for five, evenly-spaced tractive effort commands, accelerating from a stop.
- Time to travel one kilometer from a standing start with a maximum power command.

- Acceleration performance at during the AW3 braking tests required in the following section.

15.5.4 Braking Tests

The first series of tests shall be run at AW0, the second series of tests shall be run at AW2, and a third series of tests shall be run at AW3. Braking runs shall be made for both normally configured stops, in which both dynamic and friction brake are blended to provide the specified performance, and for all friction brake stops. In all friction stop tests, for each run, brake discs shall be cooled to a maximum of 120^{o}C as measured by thermocouples before initiation of any test. Performance requirements are as noted in Sections 2, 10 and 12.

- Blended maximum service brake stops from 70 and 50 km/h
- Blended minimum service brake stops from 32 km/h
- All-friction maximum service brake stops from 70 and 50 km/h
- All-friction minimum service brake stops from 32 km/h
- Emergency stops from 70 and 50 km/h
- Tests designed to determine the specification compliance of the track brake system

15.5.5 Thermal Capacity Tests

One car shall be fully instrumented and used to verify compliance with the duty cycle requirements specified in Sections 2, 10 and 12.

15.5.6 Wheel Spin/Slide

All power and braking modes shall be used in verifying compliance with all wheel spin/slide provisions given in Sections 2, 10 and 12. The following signals shall be monitored during spin slide testing to verify compliance in the manner required by SDOT.

- Tractive effort command and effort delivered per inverter
- Pressure signals per truck
- All wheel (or axle) speed signals on the spin/slide test train

15.5.7 Auxiliary Inverters

The Contractor shall operate auxiliary inverter instrumentation throughout all car performance testing to verify consistent, reliable inverter performance. Chart recordings which contain representative samples of inverter operating characteristics, taken during the auxiliary inverter design conformance test and these car performance tests, shall be copied and included in an inverter test report.

15.5.8 Onboard Energy Storage System

The onboard energy storage system operation shall be monitored during all vehicle operation testing. Additional test runs shall be conducted to confirm the operation requirements stated in Sections 2 and 9.

15.5.9 Parking Brake

A parking brake system test shall be performed on the first car. Compliance with Section 2 shall be demonstrated by measuring the force required to move the car with the parking brake applied.

15.5.10 Ride Quality

Ride quality tests shall be performed on the first car. Tests shall demonstrate compliance with the ride quality specifications contained in Section 2.

As a minimum, ride quality tests shall consist of operating the car at speeds of 40 and 70 km/h over track selected by SDOT under two load conditions: AW0 and AW1. Instrumentation capable of measuring the magnitude of the vertical, longitudinal, and lateral shocks and vibrations expected shall be provided and monitored by the Contractor. Sensing units shall be located on the car floor above the intersection of the car longitudinal center line and the following: a power truck transverse center line; a center truck transverse center line; the center of one section of the car between trucks; and at three seat locations as determined by SDOT. Provision shall be made for recording vertical, lateral, and longitudinal shocks and vibrations concurrently. Weights used to simulate AW1 shall be provided by the Contractor. Acceptability of the ride quality will be determined by an analysis of the recorded root-mean-square accelerations.

15.5.11 Noise and Vibration

Sound level and vibration tests shall be performed on one car, at AW0 car weight, to confirm that the readings are compliant with Section 2.

Sound measurements shall be taken on at grade, newly-ground, welded rail and where reflections from nearby walls, floor, or other equipment will not influence the directly radiated sound by more than 2 dB. Measurements shall be made with an ambient sound level not less than 10 dB below the sound level produced by the equipment being measured when evaluated using the same scale or octave band.

For these tests, the following shall be recorded:

- Description of sound level or vibration source being measured, including pertinent statistical information
- Description of the environment where sound level or vibration source is measured, including a sketch showing source position
- Operating conditions of sound level or vibration source during measurements
- Pertinent meteorological data
- Locations and orientations of microphones with respect to sound level source
- Equipment used for making measurements
- Description and measurements of ambient sound levels
- Data obtained, including range of variation
- Instrument settings, corrections, and calibration records

15.5.12 Horn and Bell

The horn and bell, as mounted on a completed car, shall be tested for conformance to the requirements of this Specification. This requires testing of both ends of a car.

15.5.13 Electromagnetic Compatibility

An EMI/EMC test shall be performed on the first car per the requirements of Section 2 and the EMI test plan.

15.5.14 Jacking Test

The first car shall be tested to demonstrate compliance with the jacking load requirements of Section 3.

15.5.15 Coupler Test

It shall be demonstrated that an operational vehicle can tow an inoperative vehicle over the entire First Hill Streetcar alignment by use of the emergency coupler bar.

15.5.16 Ducting Watertightness Test

The fresh air and electric equipment ventilation intake ducts in the car roof shall be water tested with the ventilating fans running at full speed to determine the effectiveness of the water-excluding features of the duct work. At the conclusion of the test, there shall be no evidence of moisture in the ducts downstream of the water excluding features.

15.5.17 Air Leakage

To assure positive internal car body pressurization, the first car shall be given an air leak smoke bomb test with the interior pressurized to a minimum of 125 Pa. All openings related to ventilation shall be sealed during this test. All apparent leaks shall be evaluated and a fleetwide correction implemented by the Contractor.

15.5.18 Air Balance

The air balance test and a car pressurization test shall be performed to verify conformance with the requirements specified in Section 7, with "dry" evaporator coil condition. The volumes of fresh, recirculated and exhaust air, and the total volume of air delivered by the circulating blowers, shall be measured and recorded, along with the conditions of the air (^{o}CDB, ^{o}CWB, and barometric pressure).

The blower motor current, volts, power consumption and speed shall conform to the HVAC manufacturer's design data and motor specifications.

The Contractor shall make all necessary adjustments to conform to the requirements of Section 7.

15.5.19 Vehicle HVAC System

The test of the vehicle HVAC system shall be conducted by the Contractor, with the assistance from the HVAC unit manufacturer, to verify vehicle HVAC system compliance with the requirements of Section 7. This test may be conducted in a climate room, or in an enclosed facility, such as a paint booth, where the “ambient” temperature requirements specified in Section 7 can be achieved. Electric baseboard heaters and humidifiers shall be used to simulate the passenger, sensible and latent, and solar loads inside the car. Portable data logging equipment shall be used to record temperature at a minimum of 30 locations throughout

the car, representative of seating and standing passengers, including operator's cab and articulation section.

The car shall be exposed to an agreed-upon high ambient temperature condition for a minimum of six (6) hours, without HVAC system operation. Following this "soaking", the pull-down test shall be performed, and time required for achieving and stabilization of the required car interior temperatures shall be measured for information.

Testing shall include a cooling test at the design conditions of Section 7 and the including cooling tests required by Section15.4.4, except that actual interior passenger and solar loads shall be simulated inside the car, instead of regulating the return air temperature.

Following stabilization for each test condition, the temperatures shall be recorded every minute for 30 consecutive minutes in order to determine temperature swing as the HVAC equipment cycles. Car interior temperatures shall not vary by more than 3^{o}C per the following:

- 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, except for the articulation section
- At any given time, except during pull-down and warm-up, in the plane 1200 mm above the floor and any point directly underneath, 150 mm above the floor
- At any given point within the car after stabilization, with the doors closed, due to cycling of HVAC equipment

All significant events and data (such as refrigeration and heating equipment cycling) shall be recorded, with corresponding temperatures and pressures as applicable for each test. The test shall also verify proper operation of HVAC equipment during cooling and heating operation.

After all tests have been completed, samples of the refrigerant and compressor crankcase oil shall be taken and analyzed for contaminants by an approved laboratory. Test results shall conform to the requirements of ARI Standard 700, except that moisture levels of up to 30 mg/kg are allowed and the high boiling residue requirement is not applicable.

15.5.20 Door and Bridgeplate Operation

Before shipment, the first vehicle shall have all doors and bridgeplates operated for 1,000 continuous trouble-free cycles.

Any door/bridgeplate or door/bridgeplate control failure occurring prior to completion of the test on the first car will nullify the test, and the test shall be re-run completely after the fault has been corrected.

15.5.21 Light Intensity

Light intensity readings shall be taken (without light from other sources) on the first car to verify conformance with the requirements in Section 8.

15.5.22 Communication Equipment

15.5.22.1 PA System and Automatic Passenger Information System

Verify the design requirements of the PA and APIS systems, Sections 13.3, 13.4 and 13.5

The intelligibility of the PA and APIS systems shall be tested according to ANSI S3.2, as specified in Section 13.3.

The amplifier automatic volume control shall be test per Section 13.3.2.

The accuracy of the distance calculation of the APIS shall be tested over the SDOT alignment.

15.5.22.2 Automatic Passenger Counting System

The accuracy of the APC shall be tested for simulated unloading and loading of passengers, per 13.7.

15.5.22.3 CCTV

Confirm design requirements per Section 13.9, at minimum, viewable areas within the interior and exterior, storage capacity and functional requirements.

15.5.22.4 TWC

Verify design requirements per Section 13.14.

15.6 Production Conformance Tests

All equipment on each of the cars shall be given functional tests at the Contractor's facility prior to shipment. The test to be performed on each component, system or the car shall be in accordance with the standards listed in this specification or an approved test plan for the component, system or car. The test reports of all Production Conformance tests shall be included in each "Car History Book" as specified in Section 19.

15.6.1 Electrical Apparatus

Each component that is separately assembled, housed, and wired into a package unit prior to installation in the car shall be tested at its point of manufacture and a certified test report, signed by the responsible Quality Assurance representative of the manufacturer, shall be furnished to SDOT. Control and communications equipment shall be tested for function according to a procedure prepared by the manufacturer. Each test of electrical equipment shall include an insulation test as specified herein.

15.6.2 Air Conditioning Unit

Each air conditioning unit shall be tested with a heat load applied to both the evaporator and condenser coils.

The unit shall be given a complete functional test to verify capacity modulation, control points of all pressure switches and all return air and fresh air thermostatic control points. Power consumption of all motors, evaporator and condenser fan motor speeds, system pressures and temperatures, and the applied loads to the evaporator and condenser shall be recorded. The system refrigerant charge and the refrigerant condition (wet or dry) shall be recorded. The oil level in the compressor shall be recorded. Any abnormal condition shall be corrected and the associated test repeated.

The unit heat staging and the functioning of the overheat protection devices, as specified in Section 7, shall be verified.

The manufacturer shall conduct insulation resistance and high potential tests on each unit per the requirements of this specification.

15.6.3 Motors

Each traction motor, ac auxiliary motor, and dc motor shall be given a "routine" test by the manufacturer in accordance with IEC Publication 60349, IEEE Standard 11, or IEEE 112, as appropriate. Motor balance shall be dynamically tested in accordance with NEMA MG 1-12.06.

15.6.4 Traction Gear Units

Each traction gear unit shall be given the manufacturers "routine" test, which shall include, as a minimum, the following:

- Gear tooth mesh shall be checked to verify that it is within the manufacturer's tolerances before the gear unit is operated
- No load operation at 40 km/h equivalent car speed for 10 minutes in each direction. Noise and vibration produced by each gear unit and gear sump oil temperature shall be continuously monitored. All gear units which produce abnormal oil temperature or noise shall be rejected.

15.6.5 Traction Inverter

Each traction inverter shall be given a "routine" test by the manufacturer in accordance with IEC 61287-1 or IEEE Std 16 to verify compliance with all aspects of the following for all nominal conditions defined in Section 2:

- All output and control requirements
- Performance requirements
- Fault detection and annunciation requirements
- Insulation and isolation requirements. Insulation shall be tested per the requirements of this specification.

15.6.6 Onboard Energy Storage System

Each onboard energy storage system shall be given a "routine" test by the manufacturer in accordance with IEC 61287-1 or IEEE Std 16 to verify compliance with all aspects of the following for all nominal conditions defined in Section 2:

- All output and control requirements
- Performance requirements
- Fault detection and annunciation requirements

15.6.6.1 Insulation and isolation requirements.

Insulation shall be tested per the requirements of this specification.

15.6.7 Auxiliary Power Supply

Each auxiliary power supply shall be given a "routine" test by the manufacturer in accordance with IEC 61287-1 or IEEE Std 16 to verify compliance with all aspects of the following for all nominal conditions defined in Section 2:

- All output and control requirements
- Performance requirements

- Fault detection and annunciation requirements

15.6.7.1 Insulation and isolation requirements.

Insulation shall be tested per the requirements of this Specification.

15.6.8 Low Voltage Power Supply and Battery Charger

Each low voltage power supply shall be given a "routine" test by the manufacturer in accordance with IEC 61349 or IEEE Std 16 to verify compliance with all aspects of the following for all nominal conditions defined in Section 2:

- All output and control requirements
- Performance requirements
- Fault detection and annunciation requirements
- Insulation and isolation requirements. Insulation shall be tested per the requirements of this Specification.

15.6.9 Battery

Five percent of the batteries supplied shall be given a capacity test at the point of manufacture. The test shall be at the 5 hr rate, at 20^{o}C ambient temperature in accordance with section 4.2.1 of IEC Publication 623.

15.6.10 Friction Brake Equipment

All electrical and electronic assemblies shall be subjected to an insulation resistance and high potential test per the requirements of this Specification.

Each hydraulic pump unit shall be given a functional test and a capacity test.

All valves shall be functionally tested and certified for performance in accordance with manufacturer's specifications and test codes.

All electrical and electronic assemblies shall be functionally tested and certified for performance in accordance with manufacturer's specifications and test codes.

15.6.11 Communication System

All electrical and electronic assemblies shall be subjected to an insulation resistance and a high potential test per the requirements of this Specification.

All electrical and electronic assemblies shall be functionally tested and certified for performance in accordance with manufacturer's specifications and test codes.

15.6.12 Truck Quality Testing

All production truck welds, including the frame, bolster and any other primary structural members, shall be subjected to magnetic particle or dye penetrant inspection. Critical welds shall be inspected by radiography, or by section and etch, on 5% of the trucks chosen at random. Magnetic particle inspection shall be in accordance with ASTM E 709. Dye penetrant inspection shall be in accordance with ASTM E 165. Cast trucks shall be 100% magnetic particle inspected.

If defects are found during sampling inspection, the Contractor shall positively locate the beginning of such defects in previous truck frames and apply appropriate corrective action.

15.6.13 Wheel Back-to-Back Dimensions

All wheel-axle assemblies shall be measured to verify conformance with back-to-back distance requirements.

15.6.14 Shunt Resistance

All wheel-axle-wheel and wheel-axle-ground brush assemblies shall be measured to verify conformance to shunt resistance requirements.

15.6.15 Vehicle Watertightness Test

For each car, all areas of the car sides, ends, and roof, including doors and windows, shall be given a complete test for watertightness. Tests shall be made before installation of sound deadening material, thermal insulation, and interior finish. Water shall be sprayed from nozzles which are spaced no more than 1 meter from, and aimed directly at, the surface being tested. Not less than 26 liters per minute shall be delivered to each square meter of surface being tested, and the nozzle velocity of the water shall be not less than 45 meters per second.

All spray applications shall run for 10 minutes before inspection for leaks begins, and shall run continuously during the inspection. The watertightness test shall also be performed on individual underfloor boxes required to be watertight during the test of each complete carbody. During test of the boxes, spray shall be directed at the exposed sides and ends of the boxes as would normally occur during car washing operations and as a simulation of water spray from the wheels.

Traction motor lead connections shall also be given a water test. Water flow rate and velocity shall be the same as for the carbody water test.

15.7 Vehicle Static Tests

The tests listed in this section shall be performed by the Contractor on each assembled car prior to the vehicle acceptance test.

15.7.1 Vehicle Wiring

Vehicle wiring acceptance testing shall be performed at the Contractor's facility on all cars after the wiring and equipment installation is completed and shall consist of the tests described below. The integrity of electrical insulation and connections shall be confirmed where specified below by performing continuity, insulation resistance, and high potential tests on the completed vehicle.

15.7.1.1 Wiring Continuity Checks

All circuits shall be tested to ensure continuity and correct polarity of equipment and devices. All frame grounds and terminal connections shall be checked for tightness.

15.7.1.2 Insulation Resistance Testing

Insulation resistance tests shall be conducted before high potential tests are conducted in accordance with the requirements of Section 15.2.

15.7.1.3 High Potential Tests

A high potential test shall be conducted after the insulation resistance tests are completed and passed. The high potential test shall be conducted on all circuits within the vehicle in accordance with the requirements of Section 15.2.

15.7.2 Door, Bridgeplates, Operators and Controls

The doors, bridgeplates, and their operating equipment shall be tested and adjusted on all cars to assure smooth functioning, attainment of the required speed of operation, and proper operation of controls, signals and interlocks, as specified in Sections 5 and 6.

All doors and bridgeplates shall be operated a minimum of 100 consecutive, successful cycles. Initiation of the cycling shall be through the control line. Proper forces for opening and closing shall be verified on every door and bridgeplate before and after the above cycling.

The obstruction detection features shall be checked for proper operation and adjusted prior to the start of the cycling test. This feature shall operate properly, without the need for readjustment, at the end of the cycling tests.

Any door, bridgeplate or control failure occurring prior to completion of the test will nullify the test, requiring that the test be restarted from the beginning following documented correction of the failure.

15.7.3 Air Conditioning

The air conditioning system shall be functionally tested by simulation of inputs with the Portable Test Unit in all cars. The operation of the thermostatic control system shall be demonstrated by using the PTU. The sequence of capacity modulation, as applicable, and system pump-down, shall be verified. The system refrigerant charge and the refrigerant condition (wet or dry) in liquid sight glasses shall be recorded. The oil level in the compressor shall be recorded, if applicable. Any abnormal condition shall be corrected and the associated test repeated.

15.7.4 Heating

The heating system shall be functionally tested in all cars by simulation of inputs with the PTU. The operation of the thermostatic control system shall be demonstrated by use of the PTU. Heat shall be applied to the overhead heaters without air flow and the high limit control switch shall be cycled three times. The test shall be successful when the back-up protection device is not activated. During the test, power consumption shall be recorded and proper operation of all controls shall be verified.

15.7.5 Headlights and Stoplights

The headlights and stop lights on each car shall be aimed and adjusted to meet the requirements of Section 8.

15.7.6 Friction Brake

The Contractor shall perform a complete functional test of the friction brake system prior to shipment of each car from its plant. Tests shall include, as a minimum, verification of brake cylinder pressure settings, control and indicator verification, system leakage tests, response to dynamic brake feedback signals, and a functional test of the brake fault detection system.

15.7.7 Communication

All communication equipment and systems shall be functionally test to verify conformance with the requirements of Section 13.

The PA system, APIS and each PEI shall be tested for clarity (intelligibility) of voice transmission and reception.

The APC shall be tested to verify accuracy of system.

The CCTV and exterior side view CCTV shall be tested to verify proper positioning of cameras.

15.7.8 Truck Quality Testing

All production truck welds, including the frame, bolster and any other primary structural members, shall be subjected to magnetic particle or dye penetrant inspection. Critical welds shall be inspected by radiography, or by section and etch, on 5% of the trucks chosen at random. Magnetic particle inspection shall be in accordance with ASTM E 709. Dye penetrant inspection shall be in accordance with ASTM E 165. Cast trucks shall be 100% magnetic particle inspected.

If defects are found during sampling inspection, the Contractor shall positively locate the beginning of such defects in previous truck frames and apply appropriate corrective action.

15.7.9 Wheel Back-to-Back Dimensions

All wheel-axle assemblies shall be measured to verify conformance with back-to-back distance requirements.

15.7.10 Shunt Resistance

All wheel-axle-wheel and wheel-axle-ground brush assemblies shall be measured to verify conformance to shunt resistance requirements.

15.8 Vehicle Acceptance Testing

The following acceptance tests shall be performed by the Contractor in Seattle unless otherwise approved by SDOT. All tests shall be performed on all cars.

Prior to the initiation of performance testing, the vehicle shall be jointly inspected by SDOT and the Contractor. The Contractor shall make such adjustment, repair, or replacement as required for proper operation or as deemed necessary by SDOT.

The following tests shall be performed by the Contractor, or under its direction, as a condition of acceptance of the cars.

15.8.1 Functional Tests

A complete, orderly, and comprehensive test of each and every vehicle system, including car lighting and all auxiliaries, shall be made to verify its proper operation. These tests shall be performed on each vehicle prior to track operation.

15.8.2 Vehicle Performance Test

The Contractor shall demonstrate, via dynamic testing on the First Hill Streetcar alignment, that each car's tractive power, dynamic braking, friction braking, and track braking systems meets the criteria used for the Vehicle Design Qualification Tests in Sections 15.5.3, 15.5.4, 15.5.6, and 15.5.8, except the vehicles shall be only tested at AW0..

- Instrumentation requirements for the acceptance test shall be as specified in Section 15.5.2.

Any adjustments required as a result of the performance tests to obtain values corresponding to the performance levels shall be made by the Contractor prior to delivery and shall be noted the car's history book.

15.8.3 Post-Performance Testing

Each vehicle shall be given an operational test of a minimum of 500 kilometers prior to final acceptance. The operational tests shall be performed on the intended alignment in mixed traffic. During the last 100 kilometers, there shall be no failures of equipment. If a failure occurs in the last 100 kilometers, the 100 kilometer test will be restarted after correction of the problem.

Vehicles shall be operated as necessary for overhead contact wire adjustment, substation protective relay adjustment, and signalization verification.

15.9 Vehicle Delivery

Following successful completion of all tests specified in Section 15.8, the cars shall be formally delivered to SDOT for Acceptance.

15.10 CDRL

The following submittals are required:

15-1 Master Test Plan (Section 15.1.2)

Qualification Tests:

Component and System Level

15-2 Flammability and Smoke test procedures and reports (Section 15.3.1)

15-3 Ac traction motor qualification test procedure and report (Section 15.3.2)

15-4 Ac auxiliary motor qualification test procedure and report (Section 15.3.3)

15-5 Traction gear unit qualification test procedure and report (Section 15.3.4)

15-6 Auxiliary power supply qualification test procedure and report (Section 15.3.5)

15-7 LVPS and BC qualification test procedure (Section 15.3.6)

15-8 Truck frame qualification test procedures and report (Section 15.3.7)

15-9 Carbody structural test procedure and report (Section 15.3.8)

15-10 Propulsion system qualification test procedure and report (Section 15.4.1)

15-11 Friction brake system qualification test procedure and report (Section 15.4.2)

15-12 Door system qualification test procedure and report (Section 15.4.3)

15-13 Unitized HVAC system qualification test procedure and report (Section 15.4.4)

15-14 Onboard Energy Storage System qualification test procedure and report (Section 15.4.5)

Car Level

15-15 Propulsion and Braking qualification test procedures and report (Sections 15.5.2 through Section 15.5.8)

15-16 Onboard Energy Storage System qualification test procedures and report (Section 15.5.9)

15-17 Ride Quality qualification test procedure and report (Section 15.5.10)

15-18 Noise and vibration qualification test procedure and report (Section 15.5.11)

15-19 Horn and bell qualification test procedure and report (Section 15.5.12)

15-20 Electromagnetic compatibility qualification test procedure and report (Section 15.5.13)

15-21 Jacking qualification test procedure and report (Section 15.5.14)

15-22 Coupler qualification test procedure and report (Section 15.5.15)

15-23 Watertightness qualification test procedure and report (Section 15.5.16)

15-24 Air leakage and air balance qualification test procedure and report (Section 15.5.17 and 15.5.18)

15-25 HVAC qualification test procedure and report (Section 15.5.19)

15-26 Door operation qualification test procedure and report (Section 15.5.20)

15-27 Lighting intensity qualification test procedure and report (Section 15.5.21)

15-28 Communication Equipment (Section 15.5.22)

Conformance Tests:

Component and System Level

15-29 Electrical apparatus conformance tests procedures (Section 15.6.1)

15-30 HVAC unit conformance test procedure (Section 15.6.2)

15-31 Motor conformance tests, procedures (Section 15.6.3)

15-32 Traction gear unit conformance test procedure (Section 15.6.4)

15-33 Propulsion inverter conformance test procedure (Section 15.6.5)

15-34 Onboard Energy Storage System routine test procedure (Section 15.6.6)

15-35 LVPS and battery charger conformance test procedure (Section 15.6.7)

15-36 Battery conformance test procedure (Section 15.6.8)

15-37 Friction brake equipment conformance test procedure (Section 15.6.9)

15-38 Communications system conformance test procedure (Section 15.6.10)

15-39 TWC system conformance test procedure (Section 15.6.11)

15-40 Truck Frame Welds conformance test procedures (Section 15.6.12)

15-41 Wheel Back-to-Back conformance test procedure (Section 15.6.13)

15-42 Shunt Resistance conformance test procedure (Section 15.6.14)

15-43 Watertightness test procedures (Section 15.6.15)

Vehicle Static Tests:

15-44 Vehicle wiring tests procedures (Section 15.7.1)

15-45 Door test procedures (Section 15.7.2)

15-46 Air conditioning system test procedure (Section 15.7.3)

15-47 Heating system test procedure (Section 15.7.4)

15-48 Exterior lights test procedure (Section 15.7.5)

15-49 Friction brake system test procedure (Section 15.7.6)

15-50 Communications system test procedure (Section 15.7.7)

Vehicle Acceptance Testing

15-51 Vehicle Functional Tests (Section 15.8.1)

15-52 Vehicle Performance Testing (Section 15.8.2)

15-53 Burn-in test procedure (Section 15.8.3)

END OF SECTION

SECTION 16

MATERIALS AND WORKMANSHIP

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SECTION 16

MATERIALS AND WORKMANSHIP

16.1 General

16.1.1 Quality

This Section defines the minimum performance requirements for materials to be used in the construction of the streetcars and establishes minimum guidelines for workmanship. It identifies mandatory government requirements and industry specifications controlling the quality of specific materials and components and the construction methods. Alternatives will be considered.

The Contractor shall ensure that all equipment, materials, manufacturing, assembly, and installation processes and practices are in full conformance with the intent and the requirements of this Specification as well as with proven and recognized industry practices and recommendations.

16.1.2 Standards

All materials shall conform to the appropriate industry standards for use on rail transit equipment. These standards include Federal or Military Specifications or Standards, the Specifications of the Aluminum Association of America, AAR, ANSI, ASME, ASTM, FRA, IEEE, IEC, EN, or other requirements as specified herein. Foreign or international standards may be proposed by the Contractor as alternatives. The Contractor shall submit proposed standards in English for review by SDOT. A service history of equipment built to these standards may be included to demonstrate the applicability of the standard. (CDRL 16-1)

16.1.3 Storage of Material

All equipment and material intended for use in these cars shall be shipped and stored such that damage or reduction in life is prevented. All stored material subject to corrosion shall be protected by waterproof covers or coatings. Materials and equipment shall be stored under cover and off the floor or ground.

All equipment shall be stored with all ports, covers, and all other enclosure openings closed to prevent ingestion of dirt or moisture.

All dated material shall be clearly marked with the expiration date and shall not be used beyond this date. All material with special handling or storage requirements shall be handled or stored according to the manufacturer's requirements.

All material shall be clearly marked and/or stored with appropriate nomenclature to prevent misapplication.

Rejected material shall be clearly marked as such and stored in an area specifically designated for that purpose.

16.1.4 Cleaning Agents

A list of recommended cleaning agents shall be provided for all materials exposed to normal cleaning operations. The recommended cleaning agents shall be subject to SDOT review and

approval. (CDRL 16-2) This information shall also be included in the maintenance documentation for the vehicle.

16.1.5 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
- 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

16.1.6 Material Reporting Requirements

Whenever a commercial material is not covered by a specification or standard, the Contractor shall identify the material by the commercial trademark, name, and address of the Supplier. The Contractor shall submit a description and the technical data specifications of the material composition for approval. (CDRL 16-3)

The Contractor shall keep on file Material Safety Data Sheets (MSDS) for all chemical materials (paints, solvents, adhesives, etc.) used in the manufacture of the vehicle, and provide MSDS information as requested by SDOT for any questionable material. A copy of each MSDS shall be submitted to SDOT for information. (CDRL 17-4)

The Contractor shall maintain records that trace all materials to their manufacturers and production lots, and shall help verify compliance with quality standards specified or cited in this Specification.

16.1.7 Dissimilar Materials

Dissimilar materials refer to materials that corrode or otherwise become damaged when in contact with other materials.

Connection of dissimilar materials is permitted only at permanent connections and with suitable electrochemical isolation. All such isolation treatments shall be permanent and not require maintenance or replacement for the life of the car.

Dissimilar materials are not permitted at electrical connections or connections requiring disassembly for maintenance or for removal and replacement of equipment.

16.2 General Standards of Workmanship

All work, when not expressly detailed on the Contractor's drawings, shall conform to the following minimum standards of workmanship:

16.2.1 Fabrication

- Camber and sweep in rolled steel members, as received, shall not exceed AISC specifications.
- Permissible cut length variation of steel rolled steel framing members shall not exceed +/- 1/32 inch.
- Flat plates are to be sheared or flame cut. Flame cutting shall only be performed by mechanically guided, or computer controlled torch.
- Flat plate members shall be within +/- 1/32 inch on all cut dimensions.
- Maximum out of flat tolerance on all plate members shall not exceed +/- 1/32 inch.
- Structural shapes, pipe, and tube, are to be cut to length using band saw or cold cut blade saw. Cut to length by hand held torch is not permitted.
- Holes are to be drilled or die punched. Bolt holes are not to be burned by hand torch. Holes 1 1/2 inches and larger may be flame cut by mechanically guided, or computer controlled torch.
- Diameter tolerances on holes under 1-1/2 inch diameter shall be that produced by commercially available drill bits or punch and die, when new, or in like new condition (this assumes that the drill press conforms to the manufacturer's specification for spindle run-out, this tolerance is considered negligible as applied to the equipment covered under this specification). This statement does not infer that the manufacturer and/or Contractor must use only new tooling and machine tools. However, in the event of a dispute on tolerances, the commercial tolerance for new tooling will be used to judge quality.
- Spacing of holes on connection plates shall not have a variation from their detailed position greater than 1/32 inch.

16.2.2 Machining

- Machine Fits shall adhere to the ANSI / ASME Fits and Practices Standard B4.1.
- Unless otherwise specified on drawings, deviation from dimensions indicated for machine parts shall not exceed +/- 0.005 inches.
- Any surface receiving power machine cutting or profiling shall have a surface finish of not greater than 125 microinches RMS.
- Shafting shall have the ends squared by face off in an engine lathe.
- Chamfers shall be machined on shaft edges; and at edge of bore of any press on part.
- Cut edges shall be de-burred.

16.3 Joining and Fastening

16.3.1 Fasteners

16.3.1.1 General

All bolts, screws, nuts, washers, and other related fastening devices shall be plated steel, stainless steel, or aluminum. All threaded, 1/4-turn, or otherwise non-permanent fasteners shall have Phillips, tamper proof, hex socket, or hex heads. Slotted-head fasteners shall not be used unless specifically approved by SDOT for application inside equipment enclosures and for bolts 5 mm diameter or less.

Except for fasteners internal to electrical or electronic components, plastic screws, bolts, nuts, or other plastic fastening components shall not be used unless approved.

Protruding screws, mounting bolts or similar items will not be permitted either on the interior or exterior of the car, except for those appointments which cannot be built into the structure in any other manner. Interior or exterior screws, bolts, and nuts exposed to passengers shall be used only if approved.

All fasteners used for access panels, equipment box covers, or other areas requiring frequent operator or maintenance access shall be captive to the cover.

Fasteners shall not be used near heat sources that will exceed the fastener manufacturer's recommended operating temperature or otherwise damage or reduce the life of the fastener.

All fasteners, except stainless steel, shall be plated for corrosion resistance. Cadmium plated fasteners are not permitted.

16.3.1.2 Threaded Fasteners

Threaded fasteners shall have screw threads conforming to ISO-metric standards. Metric fasteners shall be identified as required by applicable ASTM specifications, abstracted in "Metric Fastener Standards", Industrial Fasteners Institute, latest edition.

All structural or load carrying bolts shall be medium carbon steel conforming to the minimum requirements of SAE J429 Grade 5, or ASTM A449; with a minimum proof load of 85,000 psi. The bolt diameter shall be no less than M10, regardless of design load. Stronger fasteners shall be used if the application requires same.

All fastenings on access panels, plates, covers, or other components accessible by passengers, shall be a tamper-resistant type.

Self drilling and/or self-tapping screws shall not be used in any applications.

Stainless steel screws or bolts, nuts, flat washers, and lock washers shall be used in mounting, and in making connections, at all power resistors and other heat-producing apparatus where copper, stainless steel or other high expansion alloys are connected.

For carbon steel or other low expansion materials that produce heat, connections shall be made with SAE J429 Grade 5 zinc plated hardware.

When bolts are used to secure apparatus where the bolt head is inaccessible, a reusable mechanical locking device shall be used to prevent the bolt head from turning when the nut is being removed.

At proper torque, at least 1 screw thread shall project beyond all nuts.

16.3.1.3 Washers and Lock Washers

Washers shall conform to ANSI B18.22M, latest revision, as is appropriate for the application.

Flat washers shall be used on both sides of all electrical connections, that is, under the bolt head and the nut.

Lock washers shall not be used in structural applications or in fatigue applications where the fastener must be torqued and marked. All lock washers shall conform to International Fastener Institute (IFI) 1970 Fastener Standards.

16.3.1.4 Nuts

Prevailing torque nuts shall be regular-height, nylon-insert, self-locking ESNA stop nuts or approved equal. Self-locking nuts shall be used throughout, where appropriate for the application. Non-self-locking nuts with lock washers may be used in non-structural applications upon approval by SDOT, or where required by the Specification.

Nylon insert lock nuts shall not be used near heat sources that will exceed the manufacturer's recommended operating temperature.

16.3.1.5 Torquing

Fastener Torque Value shall be specified on the Shop Assembly Drawing. All threaded fasteners shall be torqued to a value assigned by the designer, or to standard torque values recommended by the fastener manufacturer. All safety related fasteners, including truck and brake equipment bolts, shall be "torque-striped" after torquing by paint or equal approved means.

Torquing shall be performed only by torque wrench.

16.3.1.6 Rivets

Rivets and lock pins exposed to passengers shall be stainless steel or aluminum as appropriate to the materials being joined.

16.3.2 Joint Fitting

Joints shall be properly fitted, whether exposed or concealed. Gaps between joints shall be held to a minimum and be uniform in width. The edges of panels shall have a smooth, finished appearance.

16.3.3 Metal-to-Metal Connections

Where metal is riveted or bolted to metal, contact surfaces shall be free of dirt, grease, rust and scale, and shall be coated with a metal base primer.

If aluminum parts are used for any purpose, metal-to-metal connections shall be in accordance with the latest revision of "Specifications Covering Use of Aluminum in Passenger Carrying Rail Vehicles"; Technical Report Number 524 by the Aluminum Company of America.

16.3.4 Wood-to-Metal Connections

Where wood and ferrous metal surfaces are placed together, the wood shall be coated with aluminum paint conforming to Federal Specification TT-P-38, and the metal shall be coated with a primer which conforms to Federal Specification TT-P-664.

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

If aluminum parts are used for any purpose, wood-to-metal connections shall be in accordance with the latest revision of "Specifications Covering Use of Aluminum in Passenger Carrying Railway Vehicles;" Technical Report Number 524 by the Aluminum Association of America.

16.3.5 Wood-to-Wood Connections

Where wood and wood are placed together, both abutting surfaces shall be coated with aluminum paint conforming to Federal Specification TT-P-38.

16.4 Stainless Steel

Structural stainless steel components shall be of AISI type 201L or 301LN and shall conform to the requirements of ASTM A 666 except that the carbon content shall not exceed 0.03 percent and type 301LN may contain up to 0.25 percent nitrogen.

Stainless steel used in non-structural applications shall be AISI types 201, 202, 301, 302, 304, 316, 430 or as proposed by the Contractor and approved by SDOT.

16.5 Low-Alloy, High-Tensile Steel

Structural shapes, plates and bars shall conform, as a minimum, to the requirements of ASTM A 588. General requirements for delivery of LAHT shapes, plates, and bars shall be as required by ASTM A 6.

Welded LAHT steel shall develop 20 foot-lbs Charpy V Notch impact strength in the CGHAZ (Coarse grain heat affected zone 1mm from fusion area) at 0°F.

Hot rolled or formed structural shapes may be used for non-structural applications, including equipment supports, jack pads, and clip angles.

Cold and hot rolled LAHT 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.

All LAHT steels shall be applied according to their specification properties.

16.6 Steel Castings

Steel castings used in any location throughout the car shall be selected by the Contractor for composition, heat treatment, and design best suited for the intended application.

All steel castings shall be sound throughout and shall be suitably marked with pattern and serial numbers in a manner that will not impair their strength.

All steel castings used in the truck structure, bolster, and center bearing arrangement 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 517 MPa, a minimum yield strength of 331 MPa, elongation of not less than 25% in 50.4 mm, and reduction of area of not less than 50%.

Magnetic particle inspections of all surfaces of all castings shall be conducted in accordance with ASTM E 709, by personnel certified to MIL-STD-410A, latest revision.

Where specified or required, radiographic inspection meeting the requirements of ASTM Standard E 94 and using reference radiographs to ASTM E 446 shall be applied.

Welding of castings is permitted, provided the casting supplier performs all repair welds in accordance with an approved written procedure and uses welders qualified to ASTM A 488.

16.7 Aluminum

Aluminum alloy mill products shall be identified by designations prescribed by the Aluminum Association of America and shall conform to specifications contained in the Association's publication "Aluminum Standards and Data". Castings shall conform to ASTM B 26, B 85, and B 108 for sand, die, and permanent mold castings respectively. Aluminum alloy forgings shall conform to ASTM B 247.

Protection shall be provided at the contact surface of all connections to aluminum.

The following instructions are provided for general guidance and shall not be construed to supersede conflicting recommendations by the aluminum manufacturer or by the Aluminum Association of America Technical Report No. 524.

The contact surfaces of aluminum alloy with aluminum alloy shall be etched or anodized before securing.

Aluminum alloy surfaces shall not be secured to, nor make direct metal-to-metal contact with the surfaces of copper, copper bearing aluminum alloy, brass, bronze, silver, nickel and nickel plated parts or alloys thereof, lead, tin, ferrous materials and wood.

The surfaces of aluminum alloy parts secured to steel parts shall be protected as follows:

- With a one-part polysulphide sealant or zinc chromate paste.
- Alternatively, an approved insulation joint material, which completely covers the fayed surfaces, may be used. The material shall be non-hygroscopic and, if fibrous, shall be impregnated with bitumen or some other approved water and moisture-repellant substance. Fasteners shall be primed and painted with red oxide or aluminum paint after installation.

Wood-to-metal connections shall be as specified above. The wood shall be thoroughly dried, then coated with varnish or other comparable sealant, as approved.

Carbon steel fasteners shall be cadmium plated as required above. The entire fastening, including washers and nuts, shall be plated and where possible, the head and unthreaded portion of the shank of the bolt shall be in contact with the aluminum part when secured in place. Suitable bushings may be used.

Rivets driven hot may be considered as covered by a protective oxide coating due to the heating, but the method of riveting shall, if possible, always be with the formed rivet head in contact with the aluminum alloy.

16.8 Welding and Brazing

The Contractor shall control the quality of all welding and brazing, including that of its subcontractors. Prior to performing work under this Contract, all welders shall have been tested to confirm their ability to operate the welding equipment and to make the types of welds required by the design or this document.

16.8.1 Structural Welding

All structural welding practices not specifically covered in other sections of this Specification shall be in accordance with requirements of EN287-1 for steel, EN287-2 for aluminum, and the AWS Handbook. Resistance welding shall be in accordance with MIL-W-6858. Requirements for dynamically loaded structures shall have precedence over those for statically loaded structures.

All welds shall have established weld procedures and qualifications. Weld procedure and qualification shall be identified on shop drawings specifically for that purpose.

General welding, not specified elsewhere, shall be performed to the standards of AWS D1.1. AWS D1.1 "pre-qualified" procedures may be freely employed.

Structural welding of stainless steel by the fusion-arc process shall be governed by ASME Section IX and ASME Section VIII, Part UHA. AISI 201L and 301LN stainless steels shall be treated as P-No. 8, Group-No. 3 category for reference to ASME requirements. Weld heat affected-zones (HAZ) and weld metal shall be limited to maximum allowable stress values in ASME Section VIII, Table UHA-23 for UNS S20100 stainless steel and Table UW-12 rating of welds, regardless of strength level of the base metal. Ferrite number for welds shall be between WRC4 and WRC10, or as proposed by the Contractor and approved by SDOT.

Additional information on definitions, processes or other questions pertaining to welding shall be referred to AWS Welding Handbooks, latest edition.

16.8.2 Welder Qualification

Welders shall make only those welds for which they have been qualified in accordance with the requirements of the AWS, ASME Section IX, EN 288, or other approved qualifying procedures. Records of welder qualification tests shall be made available for review upon SDOT's request.

Critical strength welds shall be stamped with an identifying symbol which can be traced to the welder who performed the work.

16.8.3 Weld Penetration

Full penetration welds are required for all structural welds unless otherwise approved by SDOT. Where partial penetration welds are proposed for structural welds, the Contractor shall provide design calculations supporting the penetration required and conduct tests to prove that production welding achieves this required penetration with a margin of safety suited to the design application. Partial penetration welds in structural connections may be made only with approval of the Contractor's formal detailed proposal.

All full penetration welds made from one side without backup shall be considered partial penetration welds. In no case shall partial penetration welds be used where they experience alternating tensile or bending loads at the weld root.

16.8.4 Inspection

The Contractor shall visually inspect all structural welds. In addition to visual inspection requirements specified by the AWS welding code, nondestructive surface inspection (dye penetrant or magnetic particle methods, as appropriate) shall be used to inspect all first production welds, regardless of whether the assembly was presented for First Article Inspection. The Contractor shall specify additional nondestructive inspection requirements for subsequent welds.

16.8.5 Weld Cleaning Requirements

All welds exposed to passengers or on the surface of truck frames and bolsters shall be completely cleaned of all slag, weld spatter, and alkaline flux residue.

16.8.6 Welding Rod or Wire

All welding rod or wire shall be purchased to AWS Specifications. Where special materials are required that are not covered by these or other applicable AWS welding material specifications, the Contractor shall submit the purchase specifications for approval.

Welding rod and wire shall be purchased in packages of convenient size, which shall be marked with the manufacturer's name and the specification, diameter and net weight of the material.

The material shall be stored in accordance with recommendations to the AWS "Structural Welding Code" to protect it from damage, and so that it can be easily identified. Material shall be issued and handled in such a way as to prevent it from being mixed with that of another specification.

16.8.7 Special Welding

Procedures for structural welding of stainless steel to LAHT, or other combinations of metals or conditions not covered by AWS specifications or codes, shall be submitted for approval.

Austenitic stainless steel electrodes or wire shall be used to join carbon or LAHT steels to stainless steels.

16.8.8 Resistance Welding

Resistance welding of stainless or carbon steels shall be in accordance with MIL-W-6858, Class B for structural applications, and Class C for non-structural applications. The Contractor shall control current, time, electrode size, shape, and tip force to produce uniform welds of specified strength which are not subject to intergranular, stress-corrosion cracking. Resistance welds shall be arranged to avoid tension or "peeling" forces on the welds under any anticipated loading condition.

Surface indentation shall not exceed 20 percent of material thickness (t) or 0.01 inch, whichever is greater; however, for exterior resistance-welded areas exposed to passenger view, indentation shall not exceed 10 percent of t or 0.005 inch, whichever is greater. Surface burn and discoloration shall be removed by an approved method.

Any deviation desired by the Contractor from the MIL-W-6858 standards including, but not limited to, weld nugget diameter, tension shear strength, and minimum spacing, shall be submitted and approved prior to inclusion in the design or in production procedures.

16.8.9 Prohibitions

The following weld process and material restrictions shall apply in all car structure welding:

- High iron powder flux type rods such as E6024, E7024 and rods known as "jet rod" may not be used in any application.
- Short-arc MIG welding using hardwire with argon, or argon/CO2 shielding may only be used on sheet metal, gauges 12 and thinner. Welding of sheet steel shall be performed to AWS D1.3.
- Galvanized steel shall not be welded to stainless steel.
- Brazing shall not be used to join stainless steel to itself or to other metals unless specifically permitted by SDOT.

16.8.10 Resistance, Spot Weld and Intermittent Weld Spacing

Spacing of resistance and spot welds shall be appropriate to the design. Spacing shall not exceed 50 mm plus twice the weld nugget diameter for any structural application, including car body side sheets. Intermittent weld spacing shall not exceed 125 mm for 50 mm weld length (40 percent minimum).

16.8.11 Torch Brazing

All brazing (above 840°F) shall follow the recommendations contained in the AWS Welding Handbook, Volume 2, latest issue. Procedures and personnel who perform brazing work shall be qualified in accordance with AWS B2.2-85, "Standard for Brazing Procedure and Performance Qualification".

Brazed joints shall present a workman-like appearance in accordance with AWS quality standards. The inner surfaces of air conditioning tubing shall be protected from oxidizing contaminants during and after brazing operations have been completed.

16.8.12 Torch Soldering

All soldering (below 840°F) shall follow the recommendations contained in the AWS Welding Handbook, Volume 2, latest issue. Procedures and personnel who perform torch soldering shall be qualified through the preparation and testing of test samples, as follows:

- Copper Piping into Fittings: Each worker designated to perform this work shall prepare 3 copper piping connections in the vertical position. The sample joints shall present a smooth, workman-like appearance, without excess solder reinforcement. Each joint shall be pressure tested using a water or air system to confirm that it is leak-free.
- Stainless Steel Lap Joints (Trim Seams): One typical trim seam sample, using the same stainless steel materials, finish and thicknesses as used on the actual car, shall be prepared by each person doing this work. The seam for evaluation shall be a minimum of 915 mm in length, and shall be setup in the horizontal, flat position during soldering. Specimen width shall be selected, or the test setup arranged, so

that premature overheating of the joint does not occur. Finished samples shall be saw-cut into 4 pieces so that 8 cross-sections of the joint may be examined. Exposed solder surfaces shall display a uniform, smooth contour and shall meet or exceed all applicable AWS quality standards.

16.8.13 Toughness of Welded Assemblies

The Contractor shall prove that all safety related welded structures such as, but not limited to, end underframes, fabricated truck frames and bolsters, and welded coupler components, have adequate toughness for the specified environmental exposure. Specifically, the weld heat affected zone (HAZ) and base metal shall resist service impact loads at the lowest specified operating temperature. Criteria for acceptance shall be shown by the Contractor to be adequate.

In the absence of prior operating history, and if no analysis requires greater toughness, the minimum impact value for Charpy V-notch specimens shall be 20 Joules of absorbed energy at the lowest specified operating temperature.

16.9 Elastomers

All elastomeric parts shall be of neoprene unless otherwise specified or approved. Elastomers shall be compounded and cured to perform as intended in the Seattle environment specified in Section 2.2.4. Elastomers shall have high resistance to ultraviolet and other solar radiation, all vehicle washing fluids, and long life. All elastomeric parts shall be resistant to ozone, oxidation, heat, oil, grease and acid.

All resilient parts shall have a design life not less than ten years.

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

Metal parts to which neoprene or other such material is cured shall be made of SAE 1020 or 1045 hot-rolled steel or approved equal, suitable for brass plating after pickling.

All door mating edges, door and window seals, and glazing strips shall be of neoprene material and shall be free of defects of material and workmanship. The durometer hardness measured with a Shore Type "A" durometer at a temperature between 20oC and 30oC shall be 70+5.

16.10 Glazing Material

The manufacture of glass panes for use in the vehicles shall insure maximum safety, as well as considering comfort, economic use, and aesthetics. Safety glass shall meet the requirements under Item 1, Table 1 of the latest revision of American National Standard ANSI Z26.1, "Safety Code for Safety Glass for Glazing Motor Vehicles Operating on Land Highways" or other approved standards as appropriate for the application.

All safety glass shall be of the laminated sheet type. Windshield material may have thermal or other treatments, but shall meet federal visibility standards.

Corners and burrs shall be ground smooth and all edges shall be seamed.

The bond between the glass and the membrane shall be such that when the glass is broken by twisting or by direct impact, there will be no separation between the laminations.

Safety sheet glass shall produce minimal distortion on a line of 45 degrees to the plane of the glass. Safety plate glass shall meet the requirements under Item 2, Table 1 of the latest revision of American National Standard ANSI Z26.1, "Safety Code for Safety Glass for Glazing Motor Vehicles Operating on Land Highways".

All safety glass shall be marked with proper identification in accordance with ANSI Z26.1, and other appropriate designation.

Plastic glazing is not permitted for use on these cars.

16.11 Floor Covering

The floor covering shall have a static coefficient of friction of at least 0.6 measured in accordance with ASTM D 2047, using leather and rubber shoe materials. Leather shoe material shall be in accordance with Federal Specification KK-L-165C. Rubber shoe material shall be in accordance with ASTM Method D 1630.

Rubber floor covering shall contain 20 percent (nominal, by weight of compound) butadiene styrene rubber, shall be non-staining, non-discoloring, and 100 percent non-oil extended. Only high quality hard clay shall be used as a filler.

No whitening (limestone) shall be used in the compound.

At room temperature, the rubber flooring shall bend around a 20 mm 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 Federal Specification SS-T-312.

Rubber flooring shall conform to the criteria below:

- A thin skinned blister is a blister, which, when finger-pushed, will collapse upon itself. Thin skin blisters of the indicated sizes are permitted as follows and shall be repaired as indicated:
    - Maximum Size: 0.75 mm height, 0.500 mm2 area with longest dimension of 50 mm.
    - Maximum Population: 3 blisters in a 300 mm by 300 mm area. There shall be only one other blister within 1 m of this area.
    - Repair Method: using a hypodermic needle, apply just enough Super Bond 420 or Bostik 1685 to bring to a flush surface.
- A thick skinned blister is a blister, which, when finger-pushed, will collapse and then return to its original condition. Thick skin blisters of the indicated sizes are permitted as follows:
    - Maximum Size: 0.75 mm height, 0.500 mm2 area with longest dimension of 50 mm.
    - Maximum Population: 3 blisters in a 300 mm by 300 mm area. There shall be only one other blister within 1 m of this area.

- Repair Method: no repair authorized.

- A lump is a blister without a void, consisting of solid material. Lumps of the indicated sizes are permitted as follows:
  - Maximum Size: 0.75 mm height, 0.500 mm2 area with longest dimension of 50 mm.
  - Maximum Population: 3 lumps in a 300 mm by 300 mm area. There shall be only one other lump within 1 m of this area.
  - Repair Method: no repair required.
- A hole is a defect which is 100% through the material. Holes of any size or population are not permitted nor shall holes be repaired.
- A thin area is a defect where the sheet is below thickness locally. Thin areas of the indicated sizes are permitted as follows and shall be repaired as indicated:
  - Maximum Size: 0.75 mm deep at the lowest point, 2000 mm2 with a longest dimension of 125 mm.
  - Maximum Population: one thin area in a 1 m by 1 m area, and there shall not be another thin area within 1 m of this area.
  - Repair Method: rub with #00 steel wool to blend this area into the normal thickness material and then buff to a normal surface finish.

16.12 Piping and Tubing (other than Air Conditioning)

16.12.1 General

All piping, valves, fittings, installation methods and testing shall be in accordance with the latest edition of ANSI B31.1 Pressure Piping. Straight runs of pipe shall be continuous and without fittings unless otherwise approved. All piping systems shall be cleaned after installation by flushing with an approved cleaning solution. All piping systems shall be pressure tested after installation in accordance with the latest edition of the code for Pressure Piping, ANSI B31.1. All leaks shall be repaired and the system retested until leak free.

Piping shall be rigidly clamped where it passes through holes in fixed members. Clamps shall not be welded, brazed or otherwise permanently fastened to any piping. Piping clamps shall be insulated with an approved elastomeric or woven mineral fabric tape to protect and acoustically insulate the piping from structure. All pipe clamps shall rigidly clamp piping to support structure. Cantilevered or other flimsy piping supports are prohibited.

Piping connections to resiliently mounted or moving equipment shall be via hose or other resilient device, as appropriate. Piping shall be clamped within 50 mm of the resilient connection.

Truck piping shall not be run on the bottom of truck side frames, transom, or bolster.

16.12.2 Hydraulic Piping, Tubing, and Fittings

All hydraulic pipes shall be sized in accordance with the function intended. Tubing shall be seamless cold drawn steel, SAE 1010 or as approved, and designed for hydraulic applications. Wall thickness shall be schedule 80 for truck mounted piping and sufficient to maintain a safety

factor of 6 at the maximum system pressure. Wall thickness in other locations shall be sufficient to maintain a safety factor of 6 at the maximum system pressure.

All hydraulic pipe or tube connections shall be via steel or stainless steel fittings. All piping and tubing connections shall utilize the same type of fitting. Fittings may be either JIC 37° flare or flareless.

All hose utilized within the hydraulic system shall be rated to withstand four times the maximum operating pressure without bursting. Hose shall not be used in locations where the temperature may exceed 100°C. All hose fittings shall be permanently fitted to the hose and the hose openings shall be capped immediately after fabrication and cleaning.

Joints shall be kept to a minimum and there shall be no inaccessible joints. Instead of elbows, tubing may be bent utilizing a bending tool designed specifically for bending of the tubing to be used. Debur all piping after cutting. All piping and pipe sub assemblies shall be cleaned and capped on all openings after fabrication. Caps shall remain in place until immediately prior to incorporation into the final assembly.

Connections to manifold ports, valve bodies, and other hydraulic system components shall use straight thread fittings with separate O-ring seals, unless otherwise approved.

Use of tapered pipe threads on any fluid carrying system component is prohibited.

Quick connect couplings shall be double shutoff with valves built into both of the mating parts and conform to the requirements of MIL-C-25427A, latest revision, or SDOT approved commercial couplings that provide equivalent performance.

All cutout cocks shall be designed to automatically depressurize the portion of the system which is being isolated by the cutout cock.

16.13 Paints and Coatings

All exterior surfaces of the car body shall be painted in accordance with SDOT approved color scheme, lettering, and numbering. Stainless steel portions of the car body shall be painted unless otherwise specified. Where stainless steel is painted, the painting procedures shall be as recommended by the paint manufacturer for that application.

16.13.1 Materials and Application

The Contractor shall submit a comprehensive document describing all paint and coatings (materials), a manufacturer's method of application and recommendations for use document, and physical quality inspection standards and methods. This document shall reference all surfaces to be painted/coated by the Contractor or his sub-contractor. (CDRL 16-5) This document does not apply to finished purchased components with finish coatings already applied by the respective manufacturer (i.e. HVAC units, small motors, small gear boxes, etc.). Traction motors and gear reducers shall have the same prescribed paint as the truck and underbody; as applied by either the manufacturer or the Contractor.

All painting materials shall be prepared and applied according to the paint supplier's recommendations. All paint materials shall be used at the consistency recommended by the paint supplier. Thinners shall be as approved by the paint manufacturer and shall be used only to the extent recommended.

All painting materials for exterior surfaces visible to passengers and staff shall be a two-part, high solids, low VOC, polyurethane paint system. All paint materials shall be repairable by SDOT, with materials and processes conforming to local, state, or federal requirements.

Metal portions of the carbody not constructed of stainless steel shall, after fabricating, be prepared for painting by grit blasting, and immediately thereafter painted with a coat of wash (etch) primer. After application of the wash primer, all metal portions of the vehicle, except the outside skin which will receive the polyurethane paint system, shall be coated with a primer according to Federal Specification TT-P-664. After erection of the framing structure and body sheets, all under car metal except stainless steel shall receive a second primer coat as specified above, plus one coat of charcoal gray enamel, per Federal Specification TT-E-527.

16.13.2 Exterior Finish Painting

Before painting any car surface that is exposed to view, all dents, gashes, nicks, roughness, or other surface imperfections or depressions shall be rectified. Rectification shall include removal so far as possible by straightening, followed by application of filler material. After straightening, the surface shall be properly prepared to receive the filler material. These surfaces shall be wash primed following straightening. Remaining imperfections shall be filled with an approved epoxy-based filler and sanded smooth. The maximum allowable filler thickness shall not exceed 3 mm.

The finished exterior shall present a high quality appearance free from sags, drips, scratches, variations in gloss, and other imperfections.

16.13.3 Apparatus and Equipment Enclosures

All apparatus and enclosures shall be painted only after all metal working activities are completed.

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

Parts of undercar equipment enclosures made from plastic or fiberglass shall be painted in accordance with the above requirements for metal portions except that the paint system shall be compatible with the plastic used.

All apparatus from suppliers shall be painted by the suppliers, under the Contractor's direction, according to the above requirements and approved color scheme, prior to installation on the vehicle.

16.13.4 Miscellaneous Painting and Finishing

Exterior stainless steel shall be cleaned with an approved alkaline cleaning solution, which shall not damage any previously painted surfaces. Other than framing structures, all hidden aluminum or ferrous materials, except stainless steel, shall be given 1 coat of a primer and one coat of an approved sealer.

16.13.5 Painting Restrictions

Any equipment or parts of equipment which would be damaged or suffer impaired operation from painting shall not be painted.

The following undercar items shall not be painted:

- Flexible conduit and fittings
- Copper tubing, piping and fittings
- Wire and cable
- Power resistors
- Heat transfer surfaces
- Electrical insulators
- Elastomeric devices
- Grounding pads

The following truck-related items shall not be painted:

- Wheels
- Axles
- Elastomeric parts
- Grease fittings
- Linkages
- Threads used for adjustments
- Electrical equipment
- Wearing surfaces

16.13.6 Interior Painting

All interior surfaces requiring paint shall be coated with an approved thermosetting epoxy powder-coating. Parts which are to be powder-coated shall be cleaned and prepared in accordance with the recommendations of the powder coating supplier and the substrate material being covered.

16.13.7 Corrosion Protection

Concealed surfaces capable of rusting or oxidation shall be properly cleaned, primed with rust inhibitor paint and painted with an approved paint. Where arc welding is performed on joints between stainless steel and other materials, the joint shall be de-scaled and cleaned and painted in accordance with this section.

16.13.8 Other Coatings

Undercoatings, acoustical insulating materials, or other coatings, where required, shall be applied to cleaned and primed surfaces and members, according to the material manufacturer's recommendations. See Section 14. All such materials shall be resistant to dilute acids, alcohols, grease, gasoline, aliphatic oils and vermin.

16.13.9 Trucks

Before installation, trucks shall be cleaned by blowing with compressed air and solvent-wiped to remove all dirt and grease. All truck components shall then be sprayed with one coat of primer

and one coat of an approved black truck paint and air dried. Truck paint shall be selected such that structural cracks will not be hidden.

16.13.10 Paint Process Documentation

The Contractor shall prepare a paint coating and application document containing procedures for surface cleaning and preparation, priming, surfacing and painting for all equipment that is painted or powder-coated whether by itself or by its manufacturers and suppliers. A detailed paint schedule showing the equipment painted, paint type and manufacturers, recommended thickness and other pertinent information shall also be included. This document shall be submitted for review and shall be made part of the maintenance manuals. (Include in CDRL 16-5)

16.14 Flammability and Smoke Emissions Requirements

16.14.1 General

All combustible material used in the construction of the car shall satisfy the flammability and smoke emission requirements cited in this section.

As a minimum, all materials used in the construction of the car interior, and materials within the air stream of passenger compartment ventilation equipment, or in close proximity to the intake of passenger compartment ventilation equipment, shall meet the requirements of NFPA 130, current edition, or the requirements stated below, whichever are more restrictive. Exterior materials shall have properties conforming to DIN 5510, Level 1, or similar standard.

Should a conflict exist between the referenced standards and the detailed requirements in this Section, the more restrictive requirements shall govern. Independent laboratory certification is required for all materials, including successful compliance with these requirements.

A matrix showing the total weight of all materials, where used, flammability and smoke emission test identity, test facility, test requirements, test results, and nature and quantity of the products of combustion, and Supplier's name shall be submitted by the Contractor during detailed design review. (CDRL 16-6)

Should the Contractor feel that the quantity of a particular material is such that it would not contribute significantly to a fire, the Contractor may request a waiver from testing for this material. The waiver shall be submitted in writing, and shall include the total weight of the material to be used, the location of the material and the distribution in the car, and Flammability and Smoke Emission test reports. (CDRL 16-7)

16.14.2 Flammability and Smoke Emission

Specific materials used on the streetcars for this Contract shall be tested to demonstrate compliance with the requirements set forth in this Section. Interior materials not listed below shall conform to NFPA 130 requirements.

TEST REQUIREMENTS FOR PASSENGER VEHICLE MATERIAL

FIRE RISK ASSESSMENT

Function of Material	Test Procedure	Performance Criteria
Interior Panels, Seats	ASTM E 162	Is < 35
	ASTM E 662	Ds (1.5) < 100
	ASTM E 662	Ds (4.0) < 200
Flooring (Covering)	ASTM E 648	CRF≥ 0.5 W/cm ^{2}
	ASTM E 662	Ds (1.5) < 100
	ASTM E 662	Ds (4.0) < 200
Light Diffusers	ASTM E 162	Is $\leq$ 100
	ASTM E 662	Ds (1.5) $\leq$ 100
	ASTM E 662	Ds (4.0) $\leq$ 200

Materials tested for surface flammability shall not exhibit any flaming running or flaming dripping.

Test reports containing the following information shall be supplied for all materials tested.

- Test Performed
- Date Tested
- Test Facility
- Test Results

16.14.3 Toxicity

Those materials and products generally recognized to have highly toxic products of combustions shall not be used.

All material used in the car construction, except for materials used in small parts (such as knobs, rollers, fasteners, clips, grommets, and other small parts) that would not contribute significantly to fire propagation or to smoke or toxic gas generation, shall be tested for toxicity using Boeing Specification Support Standard BSS-7239 or Bombardier Specification SMP 800C. Material shall meet the following toxic gas release limits (ppm) as determined per BSS-7239 or SMP-800C.

Carbon Monoxide (CO)	3500 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

16.15 Wood and Panels

16.15.1 Lumber

Lumber shall be thoroughly air seasoned or kiln dried before using and shall be dressed on all surfaces to full dimensions. Lumber shall be straight grained, free from dry rot, knots, checks, and any other defects which may impair its strength and durability or mar its appearance.

The use of wood in the car, except where specified, shall be limited to specifically approved applications.

16.15.2 Plywood

All plywood shall be manufactured to conform with the requirements of Grade - Structural I of the National Bureau of Standards Voluntary Product Standard (American Plywood Association) PS 1-83, and then stored under cover. All plywood panels shall be formed from one piece and shall be sealed with aluminum lacquer on all edges and cutouts as soon as possible after fabrication. All exposed edges of the panels, joints between panels, fastener heads, and openings of panels used in areas accessible to moisture shall be waterproofed and sealed in accordance with MIL-P-8053, paragraph 3.4, prior to installation in the car.

16.15.3 Honeycomb Panels

The term "honeycomb panels" as used in this document refers to honeycomb material bonded to melamine or to metal. Honeycomb material shall conform to Military Specification MIL-C-7438G. Bonding shall be sufficient to develop the full strength of the honeycomb material.

16.15.4 Flatness

Surfaces exposed to passengers shall not deviate from the specified contour by more than 2.5 mm in any 1 m distance. The slope of any such deviation shall not exceed 2 mm in 100 mm.

16.16 Fiberglass Reinforced Plastic

Fiberglass Reinforced Plastic (FRP) shall be a polymeric-reinforced, laminated material, composed of a gel-coated surface, fiberglass reinforcement, and a polyester, vinyl ester or other approved resin. FRP shall withstand, without any physical deformation, structural damage, or reduction in life, the environmental conditions in Section 2, and shall be resistant to acids, mild alkaline solutions and those cleaning solutions recommended by the Contractor.

FRP shall be manufactured by either open molding, hand lay-up, spray lay-up, resin transfer or matched die molding process. Production techniques shall ensure that the glass fiber reinforcement is distributed throughout the final product in such a manner as to avoid resin-rich or resin-starved sections.

Reinforced plastic parts shall have greater thickness at attachment points and edges. Exposed sharp edges are not permitted on any parts.

Additives, fillers, monomers, catalysts, activators, pigments, fire retardants, and smoke inhibitors shall be added to the resin mixes to obtain finished products with the required physical characteristics below and other requirements of this document.

Mineral filler shall not exceed 28 percent of finished weight for any preformed matched die molding process.

16.17 Electrical Fire Safety

Electrical equipment, wiring and apparatus shall conform to NFPA 130, Chapter 8.

16.18 Wire and Cable

16.18.1 General

For general car body wiring, the wire insulation shall be a flame retardant, flexible, irradiated cross-linked polyolefin material having a continuous temperature rating of 110 degrees C or 125 degree C, as appropriate. The insulation shall be rated at 2000 volts, ac and dc, in the case of wires carrying a nominal voltage greater than 100 volts ac or dc, and rated at 600 volts, ac and dc, in the case of wires carrying a nominal voltage of 100 volts or less, ac or dc. For wire sizes AWG No. 6 and larger, the insulation material shall be formulated for extra flexibility. All vehicle wire shall be reviewed and approved by SDOT (CDRL 16–7).

16.18.2 Wire Insulation for High Temperature Applications

High temperature insulation shall 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.

16.18.3 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, Teflon Polytetrafluorethylene (PTFE) type EE per Military Specification MIL W 16878/5, or radiation cross-linked polefin insulated wire, as described above..

16.18.4 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.

16.18.5 Multi-Conductor Cables

Multi-conductor cables shall be constructed using wiring as described above. For high temperature applications, the cable shall conform to MIL-C-27072, with Type V connectors, Style 4 sheaths, Class D jackets (if needed) and shields (if needed).

All conductors in multi-conductor cables shall be color coded or otherwise permanently identified as approved.

16.19 Wiring Installation

16.19.1 General

Wire shall be applied as specified in 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”, NFPA 130, and IEEE Std 16 “IEEE Standard for Electrical and Electronic Control Apparatus on Rail Vehicles” as appropriate or as specified in this document.

All car wiring shall be in conformance with 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.

16.19.2 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.

16.19.3 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.

16.19.4 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.

16.19.5 Routing of Wiring

16.19.6 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 SDOT 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.

16.19.7 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.

16.19.8 Wiring Support

Refer to APTA RP-E-002-98 Section 4.9.

16.19.9 Spare Wires

Each harness or group of wires between equipment enclosures shall contain a minimum of 10 percent spares, but no fewer than two spares for each wire size. All spares for all wiring shall be submitted for approval by SDOT. Unless specifically approved by SDOT, no spare wiring shall be used by the Contractor. All spares shall be installed in connectors on terminal boards or other means as approved by SDOT.

16.20 Wiring Connections

All car wiring shall be connected via terminals and terminal boards and/or multi-pin connectors.

16.20.1 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.

16.20.2 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 16–8). 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 SDOT. 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.

16.20.3 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. (CDRL 16-9)

16.20.4 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.

16.20.4.1 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 circular or rectangular 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.

16.20.4.2 Non-waterproof Cable Connectors

In weatherproof interior locations, the use of non-weatherproof connectors is permitted.

16.20.5 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.

16.20.6 Wire Splicing

Wire splicing is not permitted.

16.21 Electrical and Electronic Designs

Refer to Section 17 Electronic Control, Software and MDS System for material and design requirements.

16.22 Electrical Devices and Hardware

All electrical devices shall be rail industry proven.

16.22.1 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 SDOT.

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.

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 rated 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.

All relays and contactors shall be mounted and oriented as recommended by the supplier.

16.22.2 Switches

All switches shall be oiltight, 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 derated 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 derated 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 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.

16.22.3 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 16–10). 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 whenever possible.

16.22.4 High Speed Circuit Breaker

A roof-mounted, high speed circuit breaker (HSCB) shall be provided to protect the propulsion primary power circuits. The HSCB shall be operated by the low voltage power supply.

The HSCB shall have the following features: remote trip and reset, tip opening in 10 milliseconds or less, and complete arc extinguishment and fault interruption in less than 50 milliseconds. The HSCB trip values and ratings shall be coordinated with the traction electrification system supplier such that the HSCB will clear all vehicle system fault currents without nuisance trips of the wayside breakers.

The HSCB automatic reset logic shall be coordinated between the two propulsion systems, and any other systems that are fed by this device, in order to maximize vehicle availability and enhance performance and operation capabilities. In addition, the HSCB shall be capable of being reset electrically on a local basis, by means of the HSCB reset button on the local indicator panel (refer to Section 5.1). The number of electrical resets shall be limited to three within any fifteen minute period, after which resetting via the Portable Test Unit or MDS maintenance screen shall be required.

Annunciation of a tripped or open HSCB shall be provided to the operator.

16.22.5 Fuses

Fuses are not permitted except where specified or approved.

16.22.6 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.

16.23 Contract Deliverables

The following submittals are required:

16-1 Alternative standards (Section 16.1.2)
16-2 List of recommended cleaning agents (Section 16.1.4)
16-3 Material technical data (Section 16.1.6)
16-4 Material safety data sheets (Section 16.1.6)
16-5 Paint coating and application document (Section 16.13.1)
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SECTION 17

ELECTRONIC CONTROLS, SOFTWARE AND MDS

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SECTION 17

ELECTRONIC CONTROLS, SOFTWARE AND MDS

17.1 Electronic Design Standards

All electronic control equipment shall comply with the requirements of IEC 60571 “Electronic Equipment Used on Rail Vehicles, Class TX”, IEC 61287-1 “Power Converters installed on board rolling stock”, or IEEE Std 16 “IEEE Standard for Electrical and Electronic Control Apparatus on Rail Vehicles”, latest revision. Refer to Section 16 for material and workmanship standards.

17.2 Control Signal Architecture

Vehicle control signals may be either hard-wired with discrete components or transmitted using digital data communications. It is SDOT’s strong preference to utilize service proven methods to facilitate on-time delivery of the streetcars. Sub-contractor use of digital data communications within their system or Contractor use of digital data communications for fault and diagnostic information is permitted.

17.2.1 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, including 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.

17.2.2 Prescribed Discrete Control Signals

Conventional battery level trainlines shall be used for all safety-critical signals. These are described as Type I circuits in IEEE Standard 1475. At a minimum these shall include:

- Cab or Vehicle activation
- Emergency brake
- Door control commands

- Doors closed signal
- Propulsion mode
- Coast mode
- Brake mode
- Track brake
- Friction brake release signals
- Forward
- Reverse
- Sand control trainlines

17.2.3 Control System Documentation

The Contractor shall prepare documentation for the vehicle control systems for SDOT review:

- This shall include a functional description of the vehicle control systems. (CDRL 17-1)
- Vehicle control system circuit drawings and diagrams including hardwired circuit drawings, software diagrams, and functional descriptions. (CDRL 17-2)
- Sneak circuit and single point failure analysis that covers emergency loads, interlocks and safety critical functions. (CDRL 17-3)

17.3 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 Contractor shall present the selection factors for combinations I, II, III, and IV. SDOT shall select the combination to be used for these streetcars considering the Contractor recommendations. The bus shall be redundant, fast and reliable.

- Each vehicle shall include a Vehicle Network Controller (VNC). The VNC shall manage the local vehicle network(s). Data that does not need to pass between the various networks shall be restricted from so doing. The VNC may be considered as a functional entity and may be physically implemented within a more comprehensive equipment package. The VNC shall automatically identify the vehicle upon which it is installed. The VNC shall act as a router and shall also prevent local vehicle faults from interfering with train operation.
- The network system shall utilize an open design that is either non-proprietary or available from multiple sources. Complete interface descriptions and details shall be provided for SDOT review and approval. (Include in CDRL 17-4) Network components and transceivers shall be available from multiple sources.
- The network protocol shall provide services at all seven layers of the ISO/OSI communication model. All layers other than the application layer shall be transparent to the various vehicle system Suppliers.
- Communication related to real time control, such as propulsion control, shall be prioritized to the extent that anomalies in system stability and operation are prevented.

The Contractor shall present calculations of the variations in transmission time, as related to the real-time control requirements, for review and approval by SDOT. The submittal shall include a statement of acceptability by the propulsion and the brake Supplier. (Include in CDRL 17-4)

- Prior to approval of the network design, the Contractor shall submit detailed calculations of peak and average data traffic levels and calculations of network delays, for SDOT review and approval. (Include in CDRL 17-4) The network delay calculations shall include the expected average delays and the distribution of the delay times. The Contractor shall also submit peak and average traffic levels for the transmission media, as recommended by the protocol Supplier, for SDOT review and approval. (Include in CDRL 17-4) The calculated peak and average traffic levels shall not exceed 60% of the recommended peak and average traffic levels. During vehicle commissioning the Contractor shall measure peak and average traffic levels. The actual peak and average traffic levels shall not exceed 70% of the recommended peak and average traffic levels.
- Protocols shall include error detection. All nodes on the network shall collect summary statistics regarding current and historical error rates and make that information available through the Monitoring and Diagnostic System.
- Network wires shall be physically isolated from sources of EMI. Where redundant networks are employed, they shall not be run in the same conduit, wireway, or other such routing path.
- In the consideration of fault tolerance, the network design shall include an evaluation of the network topology and whether the network is operated as Peer-to-Peer or Client-Server.
- The Contractor shall describe the process whereby problems with the networks will be detected, reported, and repaired for SDOT review and approval. (Include in CDRL 17-4)

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 network shall include the WIFI IP Router specified in Section 13.11 to allow protected access to the vehicle network for the purpose of downloading APC and MDS data when the vehicle is in the yard or maintenance facility.

The contractor shall provide a description of the vehicle data network, network protocols, and transmission methodology for SDOT review and approval (CDRL 17 – 4).

17.4 Monitoring and Diagnostic System (MDS)

17.4.1 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, and car data in non-volatile memory, located within the selected subsystems and at a central data storage point on the car. The system shall automatically transmit fault data to the maintenance facility when a car enters the yard or maintenance facility.

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 SDOT review and approval, (CDRL 17 – 5), 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.

17.4.2 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 SDOT personnel.

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

1. Operating Failure Identification and Correction

- The Diagnostic System shall provide the operator and other SDOT staff, where appropriate, information concerning failures affecting car operation that they should be aware of, either because the failure is safety-related, the failure affects operating procedures, or the failure is correctable by the operator or other SDOT staff.

2. 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.

3. 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 SDOT (Include in CDRL 17 – 5).

4. 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.

5. Remote Data Management

- The vehicle MDS shall be equipped with a wireless communications transceiver for the purpose of transmitting APC and MDS data to the vehicle maintenance workstation in the shop. Communications shall be secure and encrypted to prevent unauthorized users from accessing the data or system. Refer to Section 13.11 for requirements for this WIFI IP Router.
- A workstation equipped for wireless communications shall be provided to interrogate vehicles when they are in the maintenance shop and storage yard. It shall store and analyze the data collected from the APC and MDS.

17.4.3 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 (if used)
- Friction Brake System
- Communications System
- CCTV System
- Automatic Passenger Counting System
- Propulsion System
- Energy Storage System
- Auxiliary Power System
- Diagnostic System
- Event Recorder System
- Network System

17.4.4 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 detailed information. It shall be possible for the driver to call up fault screens to assist him in failure reset or isolation.

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

Also refer to Section 5.2.

17.4.5 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 propulsion 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 and software licenses to SDOT (CDRL 17 – 6).

17.5 Vehicle Software and Systems

17.5.1 General

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

The Contractor shall provide the Computer Aided Software Engineering (CASE), ladder-logic and flow chart tools for the general car controls, monitoring, and diagnostics, including interfaces to sub-systems. These tools shall allow SDOT to read and modify the control charts and to compile revised control software that can be downloaded to the equipment. The Contractor shall provide training in the use of the tools as part of the training courses discussed in Section 18. (CDRL 17-7)

17.5.2 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 17 – 8). For reference, this Standard has the following minimum software documentation requirements:

- Software Requirements Specification (CDRL 17 – 9)
- Software Design Description (CDRL 17 – 10)
- Software Verification and Validation Plan (CDRL 17 – 11)
- Software Verification and Validation Report (CDRL 17 – 12)
- User Documentation (CDRL 17 – 13)

The Software Design Description (SDD) shall be in accordance with ANSI/IEEE Standard 1016, latest revision. The final Software Design Description shall include detailed program flow information and an input/output port map (CDRL 17 – 14).

17.6 CDRL

The following submittals are required:

17-1 Functional description of the vehicle control system
17-2 Vehicle control system circuit diagrams
- Hardwired circuits
- Software diagrams
- Functional descriptions

17-3 Sneak circuit and single point failure analysis
- Emergency loads, interlocks and safety critical functions

17-4 Vehicle Data Network
17-5 Monitoring and Diagnostic System
17-6 Portable Test Unit Software
17-7 Control signal architecture design report
17-8 Software Quality Assurance Plan
17-9 Software Requirements Specification
17-10 Software Design Description
17-11 Software Verification and Validation Plan
17-12 Software Verification and Validation Report
17-13 User Documentation
17-14 Final Software Design Description

SECTION 18

SYSTEM SUPPORT

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SECTION 18

SYSTEM SUPPORT

18.1 Manuals and Catalogs

18.1.1 Types and Quantities

The Contractor shall furnish manuals for use by vehicle operators and maintenance personnel in accordance with the requirements of this Specification. Manuals to be supplied as part of this Contract are as follows:

Operator's Instruction and Troubleshooting Manual:	10 copies per each vehicle
Maintenance, Servicing, and Heavy Repair Manuals:	2 copies per each vehicle
Parts Catalogs:	1 copy per each vehicle
Training Manuals:	10 copies per each vehicle
Special Test Equipment Manuals:	1 copy per each vehicle
Integrated Schematic Diagrams:	3 copies per each vehicle
Labor guide	1 copy per each vehicle

In the event options are awarded, the specified quantities will apply.

Delivery of two sets of first drafts and final copies of the manuals and catalogs shall occur in accordance with the following schedule:

Manual Type	Delivery of First Draft no later than:	Delivery of Final no later than:
Operator's Instruction and Troubleshooting Manual	18 months after NTP	24 months after NTP
Maintenance and Servicing Manuals	18 months after NTP	24 months after NTP
Heavy Repair Manual	18 months after NTP	24 months after NTP
Parts Catalog	18 months after NTP	24 months after NTP
Training Manuals	2 months before start of training	24 months after NTP
Special Test Equipment Manuals	18 months after NTP	24 months after NTP
Integrated Schematic Diagrams	18 months after NTP	24 months after NTP
Labor guide	18 months after NTP	24 months after NTP

18.1.2 Operator's Instruction and Troubleshooting Manual

The Operator's Instruction and Troubleshooting Manual shall contain all information needed for the optimum operation of the vehicle. (CDRL 18-1) It shall include general vehicle familiarization material, such as:

- Location, function and operation of controls, gauges, indicators and switches
- Discussion of the trucks, couplers, lights, HVAC control, propulsion, brakes, and other features of the vehicle which the operator may not be in a position to control or adjust, but of which the operator should have some basic knowledge
- Emergency procedures
- Trouble symptoms and diagnosis methods
- Operator corrective action

The manual shall be logically organized with systems and elements considered in descending order of importance. Care shall be taken that all statements are clear, positive and accurate, with no possibility of incorrect implications or inferences.

18.1.3 Maintenance and Servicing Manual

The Maintenance and Servicing Manual shall enable the maintenance staff to have all information needed for preventive maintenance inspections, on-vehicle running maintenance and adjustment, and in-service trouble diagnosis of each system, including such data as troubleshooting guides, equipment specifications and references to the Integrated Schematic Diagrams and Software Functional Description with error code troubleshooting assistance. (CDRL 18-2)

The information will include the intervals of preventive and required maintenance. The preventive and required maintenance will be listed on a chart that will define the intervals and type of maintenance for the first ten year period of the vehicle.

The manual will include the forms required for each type of inspection or required maintenance to include tasks to be performed and required parts to be used in the inspection or task.

The Maintenance and Servicing Manual shall also contain a detailed analysis of each component of the vehicle so that the maintenance staff can effectively service, inspect, maintain, adjust, troubleshoot, repair, replace, and overhaul same.

18.1.4 Parts Catalog

The Parts Catalog shall enumerate and describe every component with its related parts for the vehicles, including the supplier's number and the commercial equivalents. (CDRL 18-3)

Drawings showing subassemblies and components shall be used to permit identification of all parts down to the Lowest Level Replaceable Unit (LLRU). The LLRU is defined as the lowest level of component assembly which consists of a separate individually fabricated part. Parts common to different components, such as, for example, bolts and nuts, shall bear the same Contractor's number in all components with a reference to the other components in which they are found. Commercially available items such as common fastenings, fuses, lamps, fittings, bearings, and relays shall be identified by standard hardware nomenclature adequate to be able to purchase these items through commercial channels, in addition to the Contractor's number.

18.1.5 Training Manuals

Training Manuals shall contain sufficient material to aid the Contractor in performing the requirements of Section 18.3. (CDRL 18-4)

18.1.6 Special Tools and Test Equipment Manuals

Operations and Maintenance Manuals for each special device identified in Section 18.2 shall include setup and testing procedures for each test device. It shall also include, in a separate section, all information needed for periodic inspection and servicing requirements of the test equipment, including lubrication, inspection and adjustment of all apparatus. (CDRL 18-5)

18.1.7 Integrated Schematic Diagrams for Troubleshooting

The Contractor shall prepare, and submit for approval, Integrated Schematic Diagrams detailing all electrical, electronic, pneumatic and/or hydraulic systems in schematic fashion, including all components, wiring, and piping on the cars. (CDRL 18-6)

These documents shall be separate from the schematics and wiring diagrams in the maintenance manuals.

The Integrated Schematics shall be comprehensive and thoroughly detailed.

At a minimum, the following information shall be on the schematics:

- Zone gradations around the perimeter of each sheet for location references.
- All components shall be shown with alpha-numeric designations for all components, including supporting hardware such as connectors and pins, terminals, and similar. The designations shall be logical and clearly distinguish between different components types, such as CBxxx for circuit breakers.
- Values for components such as resistor resistances and power ratings, capacitance, circuit breaker and fuse ratings, etc.
- All relays, contactors, connectors, etc., with multiple contacts or connections shall show all contacts or connections, even if unused.
- All circuit wiring shall have numerical designations, with logical groupings for power sources, return circuits, etc.
- A complete set of device tables for all components on the schematics, including the component designation, device description, relevant data and ratings, part number as it appears in the parts manual, etc.
- Wire sizes and circuit voltages, piping sizes and system pressures, etc. Wiring for circuits differing by more than 50 volts shall have unique color codes or drawing styles. Serial data circuits shall be identified according to type (10Mb Ethernet, for example).
- Piping, hydraulic, and pneumatics diagrams shall use industry standard device symbols and nomenclature, such as defined by ANSI or similar organizations.

The schematics shall be submitted in an electronic format that is readable on a PTU screen and is formatted to print on 11 inch x 17 inch paper. Pages shall be numbered numerically and consecutively.

Diagrams will reflect SDOT's vehicle as built, and include all circuits on the vehicle.

18.1.8 Labor Guide

A Labor Guide for all major components shall be provided and include standard repair times and replacement times for all major components and the associated sub-assemblies. (CDRL 18-7)

18.1.9 Format and Content

The organization of the manuals shall treat the vehicle as an integrated system and not as a grouping of disassociated parts. The manuals shall highlight the precautions to be taken by operating and service personnel to assure their safety while operating vehicles and performing maintenance and servicing operations.

Following the issue of each publication, the Contractor shall provide revised pages covering any changes, whether required by change of design or procedures or due to error, and these revisions shall be kept current (revised every 6 months or less) during the warranty period.

All publications shall be in a robust, hardened loose-leaf notebook with tear-resistant, re-enforced pages. They shall be in five general categories and sized as follows:

- Operator's Instruction and Troubleshooting Manual: Pocket Sized
- Maintenance Manual: Standard Sized
- Parts Catalog: Standard Sized
- Training Manuals: Standard Sized
- Integrated Schematic Diagrams: 11" x 17"

  (Note: "Pocket Sized" is 5" x 7"; "Standard Sized" is 8 1/2" x 11")

The Contractor shall supply master reproducible copies of all documents. The quality of the master shall be such that duplicates may be made of the same quality as the original, approved submittals.

Manuals shall be professionally produced, printed on quality paper in a booklet with cover or 3-ring binder form with 1 additional set of each, which shall be laminated or on water-resistant paper.

All maintenance manuals, parts manuals, wiring schematics-diagrams, and component physical layouts shall be SDOT specific and accurately represent the completed as built vehicle.

All user education documents shall be in English.

18.1.10 Software

In addition to hardcopies, all manuals and the parts catalog, including drawings, shall be submitted in electronic media versions. The electronic media versions shall be revised in accordance with the hardcopy manual revisions.

18.2 Tools and Test Equipment

18.2.1 General

The Contractor shall provide all equipment specified in this Section for comprehensive in-service maintenance and testing of vehicles. All of the tools and test equipment shall be delivered at the same time as the final copies of manuals identified in Section 18.1.

PTUs for on-board diagnostics are specified in Section 17. One laptop per vehicle delivered, loaded with all necessary software installed, shall be provided. The laptop software shall not be

copy-protected, shall not require external validating devices such as “dongles”, and shall be freely copied by SDOT onto SDOT computers.

18.2.1.1 Off-Vehicle Test Equipment

Off-vehicle test fixtures and equipment shall be provided for testing and maintaining the following equipment:

- Friction brake hydraulic power equipment and calipers
- HVAC equipment
- Door and bridgeplate operators, with simulated door panel and bridgeplate masses.
- APS test rig
- Traction inverter test rig

The test equipment shall include all necessary equipment mounting fixtures, pressure or fluid sources, gauges, load cells, electrical power sources, indicators, and similar devices. A known good electronic control unit shall be provided with each fixture. Where possible, the laptop PTUs may be used to exercise and validate some aspects of performance; otherwise, dedicated electronic test units shall be provided.

Each fixture shall be supplied with an instructional manual that describes how to use the tester, in addition to expected results, and how to troubleshoot and repair the tester. Complete parts lists and schematic diagrams of the test equipment shall be included.

18.2.2 Gauges and Special Tools

All special tools necessary to perform required maintenance, as defined in the Contractor’s maintenance manuals, shall be supplied by the Contractor. Special tools include, but are not limited to, all jigs, fixtures, equipment, hand tools, power tools, or other tools and equipment necessary to maintain, repair, overhaul, assemble, and disassemble the vehicle or subsystems, that are not commonly available from commercial tool suppliers.

At a minimum, the following shall be provided:

- All special tools to activate tamper proof fasteners and access panels
- Car jacking adapters (if used)
- Light bulb and switch extraction tools
- Electrical connector pin extraction / insertion tools
- Couplers and Draft Gear
    - All wrenches, if not standard
    - All "Go," "No-Go" gauges
    - Assembly stand
- Door System
    - All gauges and jigs for door installation and adjustments
- Air Comfort System Special Tools
    - Vacuum pump

    - Electronic thermometer
    - Lifting frame
    - Refrigeration recovery, charging, test manifold
    - Holding fixture
    - Bench tester/temperature controller
    - Leak tester, electronic
- Propulsion Special Tools
    - Motor/gearbox coupling disconnector
    - All non-standard wrenches and gauges
    - High pressure oil injection tools for gears and labyrinth rings
    - Puller tools for labyrinth rings
- Truck Assembly Special Tools
    - Special tools for gearbox and coupling, disassembly, re-assembly
    - Measuring device for checking truck frame tram
    - Journal bearing puller
    - Truck assembly stand
- Friction Brake Special Tools
    - Deadweight transducer and pressure switch tester
    - Brake disc hub pulling tool
    - Seal insertion, removal tools
    - Caliper assembly tools
    - Actuator assembly tools, including parking brake
    - System bleeding & filtering equipment
    - Accumulator servicing gauge and fittings
    - Nitrogen bottle regulator
    - Portable hydraulic power pack

All gauges or special tools, other than the PTUs, that are required to maintain and overhaul the vehicle shall be supplied along with complete manuals explaining the use of the gauge or tool and its care and maintenance. Drawings showing all dimensions and materials and part lists must also be supplied.

All special tools and maintenance equipment shall be provided as two complete sets. The Contractor shall also provide part numbers and prices for all special tools and maintenance equipment to enable SDOT to purchase additional quantities.

18.2.3 Availability of Replacement Parts

The Contractor and its Subcontractors shall guarantee availability of parts or replacement parts with compatible functions for the vehicle and all systems for a period of 30 years from Contract award.

All consumable items, such as lamps, filters, lubricants, and similar shall be common components stocked in the U.S.

18.3 Training

18.3.1 General

The Contractor shall provide a draft training plan for proper operation and utilization of the systems and vehicles supplied. The final training plan will be required with the final training manuals. (CDRL 18-8)

Training shall consist of the two major categories listed below:

- Operator education; that is, basic vehicle operation including how to detect and resolve in-service problems and emergencies
- Maintenance education, including preventive, corrective, and overhaul of components and/or assemblies

The number of training hours, duration and quantities of staff to be trained listed in this Section are SDOT estimates only. The Contractor's training plan shall contain information detailing the types of training and the number of hours required to train SDOT staff. SDOT shall be the sole judge of the adequacy of the training plan offered.

The training program shall be conducted at SDOT facilities, and include classroom and hands-on instruction for a selected group of Instructors, Supervisors, Mechanics, Technicians, and Train Operators. The Contractor shall provide an adequate supply of high quality, professionally prepared material on paper, and such other training aids as required to impart the essential knowledge to the personnel involved, and provide them with accurate and up-to-date reference materials.

Manuals and other training materials to be used by the Contractor during training shall be delivered to SDOT two months before training is conducted. The manuals shall be complete, and of professional quality.

All training materials, such as training aids and lesson plans, shall become the property of SDOT at the completion of the training program.

All maintenance and operations courses shall include a combination of classroom and hands-on instruction. Written and practical tests shall be designed and given at suitable points in each course to determine the extent to which students have retained the course material and can apply the information.

SDOT reserves the right to video tape any or all training activities.

The Contractor shall work closely with SDOT's staff as training materials are being developed to ensure SDOT standards are being met with respect to the course organization, content, and overall quality of training materials.

18.3.2 Operator Training

Within ten days of the delivery of the first vehicle, the Contractor shall train one group of 5 operators. This group shall come from the core team of operators for the vehicle test program. A vehicle shall be supplied by the Contractor for this purpose and shall have all applicable systems properly operating. Ultimately, the Contractor shall train an additional 15 operators.

The Contractor shall supply two sets of DVDs which address preparing a train for service, operating a train under normal conditions, and emergency procedures for moving a train under fault conditions. The DVDs shall be supplied at least 30 days prior to the delivery of the first car. (CDRL 18-9)

18.3.3 Maintenance Education

SDOT employees shall be exposed to that depth of detail necessary for the performance of preventive, corrective, and overhaul maintenance operations for all systems and sub-systems supplied under this Specification. Students shall be afforded the opportunity to perform the more complex maintenance functions on the vehicle and in the shop, in addition to troubleshooting systems with faults artificially introduced in the equipment while using the appropriate subsystem test devices to locate and remedy these faults.

Classroom instruction for maintenance courses shall include not only the details and functioning of parts under discussion, but the essentials of their routine care, including lubrication schedules, materials, contractor's recommendations for test frequency, tolerance limits, and methods for testing, including instruments required, as applicable. When methods of access, removal, dismantling, or application are not self-evident, the instruction shall cover these matters.

Training will utilize diagnostic tools specified by equipment manufacturer.

Training shall be conducted over a maximum of 52 weeks with a minimum of 368 instructor training hours for the 1st year. SDOT may determine a need in another area and use hours from one area for additional training in another subject/module. Agenda to be decided by SDOT within 12 weeks of scheduled date.

Refresher training to include training 1 year from delivery of last vehicle Training will include a minimum 120 classroom and 120 hands-on hours for a total 240 instructor training hours. Training shall be conducted over a maximum of 52 weeks. Agenda to be decided by SDOT within 12 weeks of scheduled date.

Field instruction for maintenance courses shall include both on-vehicle demonstrations and demonstrations of basic overhaul procedures using equipment in SDOT’s Streetcar Maintenance facility.

Prior to the delivery of the first vehicle, the Contractor shall have completed instruction for one group of up to 10 persons. Subsequent to the delivery of the first car, the Contractor shall supply maintenance training to an additional 10 technicians.

Technology training shall include, as a minimum, the following:

- Introduction to the equipment, including terminology, identification of major components and their location on the car
- Detailed theory of operation
- Routine care, including lubrication schedules, adjustments, limits, inspection criteria
- Problem symptoms, troubleshooting techniques, and repair procedures

- Removal and replacement of parts and components from the streetcar
- Disassembly and reassembly for the purpose of component familiarity and any special processes
- Instruction in the use of all special tools and processes

Maintenance training shall, at a minimum, include in-depth instruction addressing the following subjects:

- Air conditioning and heating systems, including their controls
- Auxiliary power supply system, including battery
- Braking system, including all controls
- Communications system
- Network controls
- Monitoring and diagnostic system
- Lighting controls
- Propulsion system, including traction motors and controls
- Trucks, including bearings, bearing surfaces, gear units, frame, suspensions, and shock absorbers
- Door operators and controls
- Removal, replacement, and adjustment of car body materials and equipment, such as glazing, seats, doors, windshield wipers, heaters, circuit breakers and switches, light fixtures, underfloor equipment, and trucks

At least one complete set of all special tools and all test equipment (jigs, fixture, meters, gauges, vacuum pumps, temperature sensing devices, etc.) necessary to service, maintain, and overhaul each system shall have been delivered by the Contractor for use in the training program.

18.4 Spare Parts

The spare parts listed in Section CP 2 are required for this Contract. Those components listed there which are not applicable to the Contractor's specific design are not required and must be listed as "not required."

Car sets of spare parts and consumables are to be individually packaged and labeled with part numbers. Part numbers are to be the same as those depicted in the Contract required Illustrated Parts Catalog. Based on the recommended spare parts list submitted by the Contractor, actual items and quantities may be adjusted after Contract award through issuance of a Contract Change Order.

18.5 Technical Support Personnel

The Contractor shall furnish the services of at least one field service engineer at SDOT streetcar facilities, knowledgeable in each of the vehicle's systems to the level of competent troubleshooting. The field service engineer shall be provided on a full time basis starting at least one month before arrival of the first car, and shall remain until two years after acceptance

of the last car. All support personnel, including the field service engineer, shall be fluent in English.

Support personnel shall provide assistance during inspection, operation, testing and adjustment of the streetcar both before and after acceptance by SDOT.

Support personnel shall provide assistance for additional training that may be required, both before and after acceptance by SDOT.

Support personnel shall be available to work any of three 8-hour shifts, as may be required by SDOT.

The Contractor shall also insure that the expert services of equipment suppliers and designers are available, on short notice, during the same period to assist the on-site support personnel in the investigation and resolution of car and equipment malfunctions.

If requested by SDOT, the Contractor shall provide specialized on-site technical assistance within 48 hours from receipt of request during the time period from delivery of the first car to final acceptance of the last car; and within 72 hours from receipt of a request for service during the warranty period.

18.6 CDRL

The following submittals are required:

18-1 Operator's Instruction and Troubleshooting Manual (Section 18.1.2)
18-2 Maintenance and Servicing Manual (Section 18.1.3)
18-3 Parts Catalog (Section 18.1.4)
18-4 Training Manuals (Section 18.1.5)
18-5 Special Tools and Test Equipment Manuals (Section 18.1.6)
18-6 Integrated Schematic Diagrams for Troubleshooting (Section 18.1.7)
18-7 Labor Guide (Section 18.1.8)
18-8 Training Plan (Section 18.3.1)
18-9 Operator training DVDs, (Section 18.3.2)

END OF SECTION

SECTION 19

PROGRAM CONTROL AND QUALITY ASSURANCE

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SECTION 19

PROGRAM CONTROL AND QUALITY ASSURANCE

19.1 General

The design and production of the streetcars shall be controlled by the Contractor to insure that a high-quality product suitable for long and trouble-free life is produced, and that the requirements of this specification are met.

SDOT may, at its option, monitor any or all Contractor activities regarding this Contract and inspect or test any or all equipment. The Contractor shall not hinder or limit such activities.

19.2 Management Plan

The Contractor shall designate a project manager and submit a Management Plan within 30 days of NTP. (CDRL 19-1)

The plan shall include, but not be limited to, the items in Sections 19.2.1 through 19.2.5.

19.2.1 Organization Chart

An Organization Chart for the Contractor's staff, including primary personnel involved in this Contract, and key subcontractor personnel.

The Organization Chart shall also indicate management personnel responsibilities in relation to engineering, manufacturing, quality control, material procurement and other supporting functions.

Lines of both authority and communication shall be shown.

19.2.2 Work Flow Diagram

A Work Flow Diagram which clearly depicts the design, manufacturing, and testing work flow and responsibilities of the Contractor and each subcontractor or supplier for all systems and major components described in this Specification. The company name, affiliation, principal contact and position, and the location at which the work will be performed shall be included. This information shall be consistent with, and expand upon, the Contractor's approved Proposal. This Work Flow Diagram, and any changes thereto, shall be as approved by SDOT during the course of the Contract.

19.2.3 Program Schedule

Contractor shall submit a CPM (Critical Path Method) schedule indicating the reasonability of achieving the milestone dates, including the specified car delivery schedule. The CPM schedule shall indicate, as a minimum, the following:

- Activity ID
- Activity duration
- Early start and early finish dates
- Late start and late finish dates
- Activity float

As a minimum, the following activities shall be included within the schedule:

- Submittal of general arrangement drawings
- Each major system subcontractor under contract
- Design Qualification Test of each major system and component
- First Article Inspection of each major system and component
- Key design activities, including design completion dates, for both prime contractor and major system suppliers
- Anticipated date for the completion of each Design Milestone, Nos. 1 through 11, as given in Section 9 of the Special Terms and Conditions.
- Commence Car No. 1 parts manufacture
- Commence Car No. 1 subassemblies manufacture
- Commence Car No. 1 major assemblies manufacture
- Complete Carshell No. 1
- Carshell No. 1 static load test
- Commence truck manufacture (each type, if more than one type)
- Complete first truck (each type, if more than one type)
- Truck static load test(s)
- Truck fatigue test(s)
- Completion of the first car at the carbuilder's plant
- Functional testing of first car
- First Article Inspection of first car
- Shipping of first car
- Completion of the second car at the US assembly facility
- Arrival, testing (both Design Conformance and Acceptance) and delivery of each car
- Reliability Demonstration Test

Contractor shall also submit a Schedule Narrative, describing their overall approach to meeting the required milestones. The narrative should follow and describe the schedule activities to the extent practical. Items to be addressed in the schedule narrative include:

- Rationale for the given activity durations
- Rationale for the given activity interconnecting logic
- Possible work-arounds in the event of delay
- Identification of areas where delay is most likely, and the mitigation efforts planned to reduce the risk of delay.

The Program Schedule shall be updated at least every month, indicating actual achieved progress for each activity, and resubmitted to SDOT. A separate, stand-alone, more detailed

critical path schedule, showing only those activities critical to the delivery of the first car, shall also be provided.

19.2.4 Contract Data Requirements List Report

The Contractor shall submit for review and approval a Contract Data Requirements List (CDRL) Report within 30 days following NTP. The CDRL Report shall contain a consolidated listing of all CDRL submittals required by these Technical Specifications, the estimated submittal dates, and their current status. This Report shall be updated monthly.

19.2.5 Correspondence Control

The Contractor shall identify all correspondence and submittals according to a coding scheme approved by SDOT.

19.3 Meetings

Meetings shall be held between the Contractor and SDOT on a regular basis for the purpose of reviewing program progress and other program activities that cannot be readily resolved by correspondence. The Contractor shall insure that persons knowledgeable in the topics to be discussed, including subcontractors, are present or available by teleconference at all meetings.

The Contractor shall prepare minutes of the meetings and submit to SDOT for review and approval by SDOT within ten days of the meeting. SDOT shall approve the minutes or request revisions within ten days of receipt of the minutes, else the minutes shall be considered approved. (CDRL 19-2)

19.4 Monthly Progress Reports

The Contractor shall prepare a progress report each month for SDOT, starting with the first full month after award of contract. (CDRL 19-3)The report shall be submitted to SDOT no later than the 10th day of the following month (e.g., 10 July for the month of June) and shall be in a format, and with level of detail, as approved by SDOT. Monthly Progress Reports shall be based upon actual progress of the work and shall include as a minimum:

- A summary of work accomplished during the month, including actual completion dates, and start dates;
- An updated CDRL Report;
- An updated status of on-going or open engineering items;
- Dates and locations of program review meetings;
- An updated Change Order log;
- An updated vehicle weight estimate;
- Major work activities planned for the following month, including estimated remaining durations for activities in progress, and estimated start dates;
- Status of correspondence; and
- An updated schedule, including changes in the expected durations of activities, and activities not previously included on the schedule.

19.5 Design Approvals, Contractors Drawings, Documentation and Data Requirements

19.5.1 Review Procedures for Drawings, Documents and Data

The Contractor shall submit four copies of all documents, data, and assembly and installation drawings. Subassembly drawings shall also be submitted for information to facilitate the review of assembly and installation drawings. At the discretion of SDOT, the Contractor may make electronic submittals in place of hard copies. All electronic submittals shall be searchable PDF's and use electronic signatures. SDOT also reserves the right to request additional drawings to support the review of assembly and installation drawings.

When submitting drawings of structural parts or assemblies for the car body structure, equipment supports, and trucks, the Contractor shall also submit stress analyses for these parts or assemblies in summary form.

All drawings, documents, and data submitted by the Contractor shall be accompanied by a letter of transmittal listing drawing and document titles, numbers, and revisions. If more than one drawing or document is submitted at a time, the drawings and documents shall be listed in the transmittal in numerical sequence.

Drawings shall be submitted in an orderly and logical sequence to enable SDOT to readily determine and review the interface relationships between all major structural elements and their subassemblies and also between the structural elements and the attached apparatus, equipment, wiring, piping and hardware.

Except as provided below, SDOT will return submittals approved, conditionally approved, or disapproved within 30 calendar days after receipt by SDOT. SDOT will respond to the Contractor at an address designated by the Contractor. Due to SDOT's limited resources, and to prevent grouping of drawings into one large package for transmittal, SDOT will not be obligated to review more than 50 drawings, or other mutually agreeable number, in a 30-day period. In the event that more than 50 drawings are submitted for review in a 30-day period, SDOT will review them in accordance with priorities as mutually agreed to between the Contractor and SDOT.

No extension of Contract time will be allowed for revision of Contractor's drawings or documents which have been either "disapproved" or "conditionally approved". Such drawings and documents shall be resubmitted and will be reviewed and returned to the Contractor within the same time intervals as would be allotted to the drawings and documents when initially submitted. Resubmitted drawings shall accrue toward the 50 drawings per month limit.

The Contractor shall maintain a record of Contractor and Subcontractor drawing and document status. This shall include drawing and document numbers, revision letter, drawing title, date submitted, transmittal document, disposition, and the document number identifying the disposition. This status report shall be updated and submitted to SDOT not less than monthly.

19.5.2 Requirements for Drawings, Documents and Data

All dimensions shall be expressed in the SI system, and all wording shall be in the English language.

All drawings submitted by the Contractor shall be in a format approved by SDOT, and shall include a title block, drawing number, title, date, revision number, contract number, reference to next higher assembly, and signature of the Contractor's responsible engineer.

Contractor and Subcontractor drawings shall conform to the following standards:

841 x 1189 mm (DIN A0)

594 x 841 mm (DIN A1)

420 x 594 mm (DIN A2)

297 x 420 mm (DIN A3)

210 x 297 mm (DIN A4)

A revision block shall be provided for all documents, drawings, and data. The revision block shall identify the revision letter, date of revision, the initials of the Contractor's responsible engineer authorizing the revision, a description of the change, and the reason for making the change.

Wiring diagrams shall be formatted as both integrated connection diagrams and a wire list in book form ("From/To" list) based on the Integrated Schematic (Reference Section 17 for requirements regarding the Integrated Schematic Diagrams). The integrated connection diagrams shall indicate all wiring, raceways, conduits, and connections.

As a minimum, the following information shall be provided for each wire segment:

- Wire code (schematic designation)
- Origin (FROM device and terminal)
- Destination (TO device and terminal)
- Wire size
- Voltage rating
- Length
- Appropriate specifications
- Jacket color
- Harness designation

The following ANSI standards for the preparation of drawings shall apply: Y1.1, Abbreviations for Use on Drawings; V32.2, Graphics Symbols for Electrical and Electronic Diagrams; and V32.14, Graphic Symbols for Logic Diagrams. The requirements for ANSI standard graphic symbols and abbreviations may be waived by SDOT provided a system of standard abbreviations and symbols for all drawings submitted is used, and the Contractor provides SDOT with five copies of a bound booklet showing all abbreviations and graphic symbols used on drawings.

19.5.3 Drawings and Documents Requiring Approval

Drawings and documents to be furnished by the Contractor for approval by SDOT shall include, but not be limited to, those noted as CDRLs in Sections 2 through 19. SDOT reserves the right to request additional drawings or documents as required to clarify and amplify the intent of drawings furnished.

19.5.4 Approval of Contractor Documents, Drawings and Data

SDOT's approval or disapproval will be provided in one of the four following categories:

- Approved as submitted

- Conditionally Approved: The Contractor may proceed in accordance with changes indicated and shall revise and resubmit the document, drawing, and/or data for SDOT approval
- Disapproved: The Contractor shall revise and resubmit the document, drawing, and/or data for SDOT approval prior to commencing the affected portion of the work
- Accepted for Information Only: The submittal was provided as information to assist in review of a required submittal or to satisfy a request. Specific approval and comment not required.

All drawings, technical data, test procedures, test schedules, test results, test reports, progress schedules and reports, drawing lists, samples, and other data submitted by the Contractor and requiring review and approval by SDOT will be dispositioned in accordance with the above provisions.

Approval does not relieve the Contractor of the obligation to meet all of the requirements of the Contract. Approval of a document, drawing, and data which contain deviations from, or violation of, the Specification does not constitute authority for that deviation or violation. Such deviations must be specifically requested and granted.

Approval is intended to mean that SDOT is aware of the Contractor's intent and there are no objections to the apparent methods, procedures, designs, or calculations expressed in the submitted drawings or documents. It does not imply that all calculations, dimensions, materials, components or other details were checked and verified.

19.5.5 Construction Photographs

Two sets of color, unmounted progress and finished car photographs, approximately 8-in by 10-in size, with at least 100 views of the streetcar during stages representative of its complete construction, shall be furnished by the Contractor to SDOT before delivery of the last car. Each set of photographs shall be transmitted in a suitable album-type binder with transparent pockets. The album shall contain an index which identifies the photographs enclosed. The date each picture was taken, the number of the car pictured, and the location on the car shall be recorded on the back of each print. (CDRL 19-4)

SDOT reserves the right to photograph, at its expense, any or all phases of car or equipment construction, including subcontractor work, as mutually agreed with the Contractor.

19.6 Final Drawings to be Furnished by Contractor

19.6.1 List of Final Drawings

Within 90 days following shipment of the first streetcar, the Contractor shall provide SDOT with a complete list of Final Drawings to be supplied by the Contractor. (CDRL 19-5)

19.6.2 Time and Scope of Submittals

Within 90 days following the acceptance of the first streetcar, the Contractor shall supply quality Final Drawings in electronic format for the following (CDRL 19-6):

- All Contractor's and suppliers' drawings, details, bills of material, and catalog cuts that are required by SDOT for future installation, maintenance, repair and overhaul purposes

- All assemblies, subassemblies, and arrangements of the vehicle as finally furnished, modified and accepted
- All electrical schematics, electronic circuits, and wiring diagrams
- All interface control drawings down to the lowest level replaceable unit (LLRU)
- All items which are special purpose or fabricated by the Contractor
- All materials furnished by the Contractor and by its suppliers, down to and including the module and circuit board level. In every case, outline drawings shall not be considered acceptable.

All Contractor Final Drawings shall be in the as-built configuration and shall be supplied in electronic media which are fully compatible with AutoCAD, latest version.

19.7 Modification and Configuration Control

Throughout the Contract, the Contractor shall implement and maintain a configuration control system.

19.7.1 Design Changes

Changes to approved documents, drawings, and data shall be controlled by the processing of engineering change requests (ECR's). The Contractor shall submit a proposed standard ECR form for SDOT approval within 60 days after award of contract. (CDRL 19-7) The Contractor shall maintain an Engineering Change Status Report which shall list all changes, their submittal/approval status, status of implementation, and completion dates. The Engineering Change Status Report shall be included with the monthly progress report (see Section 19.4). Implementation of a change shall require incorporation in all vehicles unless otherwise approved by SDOT.

19.7.2 Component Identification and Serial Numbers

All streetcar components as mutually agreed between the Contractor and SDOT shall be permanently identified with a supplier's name, part number, and revision level.

In addition, the Contractor shall assign discrete serial numbers to certain equipment specified in this section. Serial numbers shall be in sequential, numerical order for the total quantity of each component, including spares unless otherwise approved by SDOT.

Serial numbers of all components shall be presented to SDOT as each vehicle arrives on the property or when spare components are received. The Contractor shall track all serial number transfers and prepare a list of all serial numbered apparatus installed on each vehicle for inclusion in the car history book.

At a minimum, the following equipment shall have serial numbers applied:

- HVAC apparatus
- Converters
- Inverters
- Pantographs
- Master Controller
- Door operators and controls

- Motors within equipment
- All electronic cards and ECUs
- Principal communications equipment items (not including speakers)
- Principal items of traction and braking equipment
- Truck castings or weldments
- Primary and Secondary Suspension
- Axles
- Truck frames
- Truck gear units
- Journal bearings
- Wheels
- Brake disks

19.7.3 Car History Books

Each car shall have a car history book that reflects the configuration and testing status of the car. (CDRL 19-8) The car history book shall accompany the car through the production line and be presented to SDOT when each car is accepted. Each book shall contain the following minimum information:

- Description and completion dates of all car modifications, and list of modifications pending with expected completion dates
- List of car defects that were identified by Contractor QA or SDOT personnel during construction and the disposition of each as verified by inspection
- List of serial-numbered apparatus
- Shipping documents
- Results of each functional performance and acceptance test performed on the car or any part thereof
- Wheels, journal bearings, and gear mounting records, including pressing charts
- A record of any abnormalities that occur during the manufacture of the car or any of its subsystems, including their authorized, validated, repair procedures
- Open item status list

19.8 Quality Assurance (QA) and Quality Control (QC)

The Contractor shall plan, establish, and maintain a quality assurance (QA) and quality control (QC) program that complies with ANSI/ISO/ASQ Q9001-2000 or approved equal and the FTA QA/QC Guidelines document FTA-IT-90-5001-02. The Contractor's QA/QC program shall be imposed upon all entities within the Contractor's organization and on all subcontractors whenever contract work is performed. The Contractor may accept established QA/QC plans from its subcontractors and incorporate these plans as part of its overall QA/QC program.

19.8.1 Quality Assurance Plan

The Contractor shall submit a Quality Assurance Plan (QAP) for review and approval by SDOT within 60 days of NTP. (CDRL 19-9) The QAP shall be specific to this Contract and shall describe in detail the Contractor's methods for planning, implementing, and maintaining quality in all aspects of both design and construction of the vehicles.

The QAP shall contain a company policy statement which clearly defines the authority and responsibilities of Quality Assurance personnel. At a minimum, the following QA and QC principles shall be included in the QAP and shall be implemented throughout the course of the Contract.

- The quality assurance organization shall have the authority and responsibility for establishment of the quality control system, inspection, production conformance testing, and acceptance/rejection of materials and manufactured articles in the production of the vehicle.
- The quality assurance organization shall exercise quality control over all phases of production from initiation of design through manufacture and preparation for delivery. The organization shall also control the quality of supplied articles.
- The quality assurance organization shall not report to the production manager.

19.8.1.1 QA Activities

The Contractor's Quality Assurance Plan shall provide requirements and assign the authority and means to implement procedures that control the activities listed below. The Contractor shall submit these written procedures for approval and assure effective implementation of quality assurance activities. As a minimum, procedures for the following activities shall be included as part of the Contractor's Quality Assurance Plan:

- Design and drawing control, including technical documentation and engineering changes;
- Transmission of all quality assurance requirements to procurement sources;
- Surveillance of subcontractors and suppliers;
- Receiving, source, in-process, and final inspections;
- Evaluation of procured articles against purchase order requirements;
- Production and process control;
- Equipment calibration and certification;
- Skilled personnel qualifications and certifications;
- Materials control;
- Discrepancy control;
- Functional testing;
- Quality assurance records; and
- Shipping, handling, and storing.

The Contractor shall verify that all applicable specification requirements are properly included or referenced in purchase orders of articles to be used on rail vehicles.

The Contractor shall ensure that all basic production operations, as well as all other processing and fabricating, are performed under controlled conditions. Establishment of these controlled conditions shall be based on documented work instructions, adequate production equipment, and special working environments.

The quality assurance organization shall monitor the Contractor's system for controlling nonconforming materials. The system shall include procedures for identification, segregation, and disposition.

Statistical analysis, tests, and other quality control procedures may be used when appropriate in the quality assurance processes.

19.8.1.2 Subcontractor Quality Assurance

The Contractor shall require that each supplier maintains a quality assurance and quality control program for the services and supplies that it provides. The Contractor's quality assurance organization shall inspect and test materials provided by suppliers for conformance to specification requirements. Materials that have been inspected, tested, and approved shall be identified as acceptable to the point of use in the manufacturing or assembly processes. Controls shall be established to prevent inadvertent use of nonconforming materials.

19.8.1.3 Personnel

An organization chart shall be included within the QAP to show the reporting relationships of all QA staff engaged in this Contract. Resumes of all the Contractor's QA personnel engaged in this Contract shall be included in the QAP, and SDOT shall have the right to approve or disapprove all such personnel.

Contractor production personnel performing work, inspections, or tests shall be qualified for such activity by virtue of prior experience and training, certified where required, and verified by testing where applicable. The QAP shall list all certification requirements and describe the process for verification. Records of personnel certification and qualifications shall be maintained and available for SDOT review.

19.8.1.4 Records

The Contractor shall maintain drawings and other documentation that completely describe a qualified vehicle meeting all of the requirements of the approved design. The QAP shall describe how the quality assurance organization will maintain and use records and data essential to the effective operation of its program. These records and data shall be available for review by SDOT for a minimum of three years after inspections and tests are completed. Requirements for drawings are contained in Section 19.5, for sample inspection sheets and forms in Section 19.8.2, for tests in Section 15, and for Car History Books in Section 19.7.3.

19.8.1.5 Calibration and Certification of Measuring Equipment and Tools

The Contractor shall provide and maintain the necessary gauges and other measuring and testing devices for use by the quality assurance organization to verify that the vehicles conform to the approved design. These devices shall be calibrated at established periods against certified measurement standards that have known valid relationships to national standards.

The Contractor's gauges and other measuring and testing devices shall be made available for use by SDOT to verify that the vehicles conform to all specification requirements. If necessary,

the Contractor's personnel shall be made available to operate the devices and to verify their condition and accuracy.

When production jigs, fixtures, tooling masters, templates, patterns, and other devices are used to verify construction and construction tolerances, they shall be proved for accuracy at formally established intervals and adjusted, replaced, or repaired as required to maintain quality. The Contractor shall demonstrate an effective time-cycled or usage-cycled calibration and certification program. Validity of measurements and tests shall be ensured through the use of suitable inspection, measurement, and test equipment of the range and type necessary to determine conformance with Contract requirements. At intervals established to ensure continued validity, measuring devices shall be verified or calibrated against certified standards that have a known traceable relationship to the U.S. National Bureau of Standards, or approved equal. Tooling and fixtures used as media for inspection shall be included in this program.

Every device so verified shall bear an indication attesting to the current status and showing the date (or other basis) on which inspection or recalibration is next required. Devices yielding inconsistent measurements or clearly flawed data before the stated recalibration date shall be promptly recalibrated. Items on which inspections have been performed with devices proven to be out of calibration shall be promptly reinspected. All calibration certifications shall be recorded and become part of the QA records.

19.8.2 Quality Control and Inspection Plan (QCIP)

The Contractor's quality assurance organization shall establish, maintain, and periodically audit a fully-documented quality control and inspection plan as outlined in the QAP. The Quality Control and Inspection Plan (QCIP) shall prescribe inspection of materials, work in progress and completed articles. The QCIP shall contain a list and a collection of all forms proposed to be used for the Contractor's quality control and inspection activities. (CDRL 19-10)

Sufficient trained inspectors shall be used to ensure that all materials, components, and assemblies are inspected for conformance with the approved drawings, procedures, and these Technical Specifications.

19.8.2.1 Levels of Inspection

The Contractor shall specify 100 percent or sampling inspection for discrete items of work if not otherwise specified in these Technical Specifications. Sampling procedures shall be performed in accordance with MIL-STD-1916, ANSI / ASQC Z 1.9, or other approved approach. A list of parts and material to be inspected by sampling shall be included in the QCIP along with complete details of the manner of proposed sampling.

19.8.2.2 Inspection Status

The Contractor shall maintain a system to identify acceptance, rejection, or non-inspection status of materials and components. The method of identifying inspection status shall be submitted to SDOT for review and approval.

Articles rejected as unsuitable or scrap shall be plainly marked and controlled to prevent installation on the vehicle. Articles that become obsolete as a result of engineering changes or other actions shall be controlled to prevent unauthorized assembly or installation. Unusable articles shall be isolated and then scrapped.

Discrepancies noted by the Contractor or SDOT during assembly shall be entered by the inspection personnel on a record that accompanies the major component, subassembly, assembly, or vehicle from start of assembly through final inspection. Actions shall be taken to

correct discrepancies or deficiencies in the manufacturing processes procedures, or other conditions that cause articles to be in nonconformity with the approved drawings. Inspection personnel shall verify all corrective actions and mark the discrepancy record. If discrepancies cannot be corrected by replacing the nonconforming materials, SDOT shall review and approve (or disapprove) the modification, repair, or method of correction to the extent that the contract specifications are affected.

19.8.2.3 First Article Inspections

A First Article Inspection (FAI) will be performed jointly by SDOT and the Contractor on all major components, subassemblies, and the fully assembled vehicle. The QCIP shall include a list of all those items proposed to receive an FAI and proposed inspection forms and data sheets for each FAI. FAIs may be waived at the discretion of SDOT if such items have been produced for other similar streetcar projects and there has been no change in the design or manufacturing location, process, and methods.

The Contractor shall provide an individual notice to SDOT for each FAI a minimum of 30 calendar days prior to the FAI. The Contractor shall not schedule more than two FAIs on the same date without prior approval by SDOT. First Article Inspection will not be conducted until the design drawings of the article have been conditionally approved or approved. If conditionally approved drawings are used, SDOT's conditions for approval shall be satisfied at the FAI and represented by the inspection article. An FAI package shall be submitted to SDOT 30 days in advance of each FAI that provides all necessary logistics information, any Contractor inspection reports, and a complete set of approved or conditionally approved drawings and software documentation.

When appropriate, the inspection article shall be displayed on a stand or table in a well-lit work space with skilled labor and all necessary inspection tools and gauges available for any checking or disassembly work required by SDOT.

Equipment shall be shipped from the point of manufacture only after an FAI has been approved or waived by SDOT.

19.8.2.4 Receiving Inspection

Written procedures shall be implemented to assure items are inspected at source and/or upon receipt to verify conformance to acceptance criteria of specifications and drawings. All inspections will be performed to Purchase Order requirements, specifications, and drawing requirements. Material certifications and test reports shall be retained. Contractor shall specify 100 percent or sampling source inspection for all major subsystem equipment to be purchased.

19.8.2.5 Inspection of Work In-Process

The Contractor's quality assurance organization shall maintain and direct a force of inspectors to verify that work in its shops is performed in compliance with the approved design drawings and these Technical Specifications. The Contractor shall include in the QCIP sample forms or documents to record all in-pr0cess inspections.

Discrepancies in the work shall be recorded, and departments responsible for the work shall be notified of the need for corrections. Repairs and corrections shall be inspected for conformance to drawings and the SDOT-approved rework instructions, as needed. Re-inspection acceptance status shall be indicated by the Contractor's inspectors by stamp or initials on the original of the discrepancy report. Responsible manufacturing supervision shall be notified of rework that is rejected

19.8.2.6 Hold Point Inspections

The Contractor shall establish hold points in the manufacturing process to provide for critical inspections. Hold points shall be utilized to inspect completed operations or installations. Hold points shall also be used to inspect items that are about to be covered by succeeding assembly operations. The Contractor shall use inspection forms to record the list of discrepancies noted. Nonconforming products shall not be released from a hold point area until all discrepancies have been corrected. The inspection forms shall be posted at or near the point of inspection for each vehicle and included with the Car History Book when all discrepancies have been eliminated. The QCIP shall contain a list of hold point inspections which shall include as a minimum the following:

- Each underframe
- Each car roof section
- Each articulation unit after installation
- Each carshell body section before painting
- Each carshell body section after painting
- Each truck frame
- Each assembled truck, prior to installation under a car
- Each car roof after equipment installation
- Each car watertightness test prior to installation of insulation and interior finishings
- Each car final watertightness test
- Each car interior wiring before covered by panels
- Each car interior
- Each car exterior

The Contractor shall include in the QCIP the sample forms or documents to record these inspections.

19.8.2.7 Pre-Shipping Inspection

Subsequent to final inspection by SDOT and resolution of any outstanding items, the Contractor shall prepare each vehicle so as to preclude damage during shipment. The Contractor shall prepare inspection procedures and conduct inspections for vehicles scheduled for shipment to confirm that all shipping precautions and checks have been accomplished. The Contractor shall include in the QCIP the sample forms or documents to record this inspection.

19.8.2.8 Post-Shipping Inspection

Upon arrival of each vehicle on the tracks at SDOT facilities, the Contractor shall inspect the vehicle for any damage or evidence of anomalous conditions during shipping. The Contractor shall include in the QCIP the sample forms or documents to record this inspection.

19.8.3 SDOT Audit and Inspection

SDOT may, at its discretion, perform its own QA/QC monitoring of work done under this Contract, including monitoring of the Contractor's or Subcontractor's QA and QC activities.

SDOT may perform its own inspections at its discretion. Such activities shall not reduce or alter the Contractor's QA and QC responsibilities, nor reduce or alter the Contractor's obligation to meet the requirements of these Technical Specifications.

Following NTP, SDOT shall have the right of free access to facilities of the Contractor and subcontractors in accordance with the Uniform Commercial Code. This right shall permit SDOT to inspect, examine, and test items during manufacture and shipment, and within a reasonable time after shipment.

First Article Inspections shall be performed jointly by SDOT and the Contractor (see Section 19.8.2.3)

19.8.3.1 Contractor Provision of Facilities

The Contractor shall provide to SDOT personnel a heated, cooled and adequately lighted private office with two desks and chairs in the Contractor's manufacturing facility, and SDOT personnel shall have ready access to modern toilet facilities. A private telephone line and Internet access shall also be made available. In addition, copies of all drawings, diagrams, schedules, changes, deviations, and QA records shall be made available to SDOT representative upon request.

19.8.3.2 Final Inspection

After all work is completed, the Contractor shall perform its own final inspection to written procedures prior to the SDOT inspection. Workmanship items covered by prior inspection reports shall be corrected before final inspection begins. The Contractor shall then schedule one day for SDOT final inspection of each car before shipment from the Contractor's plant to the SDOT facility.

The Contractor shall provide a qualified supervisor to accompany SDOT during SDOT's final inspection to assure that proper corrective action is taken. The Contractor shall provide labor and appropriate tools to remove or open and reapply covers and doors. During final inspection, all systems shall be operational with use of approved special equipment or power supplies.

19.9 CDRL

The following submittals are required:

19-1 Contractor's Management Plan (Section 19.2)
19-2 Meeting Minutes (Section 19.3)
19-3 Monthly Progress Report (Section 19.4)
19-4 Construction Photos (Section 19.5.5)
19-5 List of Final Drawings (Section 19.6.1)
19-6 Final Drawings (Section 19.6.2)
19-7 ECR Form (Section 19.7.1)
19-8 Car History Books (Section 19.7.3)
19-9 Quality Assurance Plan (Section 19.8.1)
19-10 Quality Control and Inspection Plan (Section 19.8.2)

END OF SECTION