CITY AND COUNTY OF SAN FRANCISCO
San Francisco Municipal Transportation Agency

Technical Specification

Procurement of New Light Rail Vehicles (LRV4)

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1 INTRODUCTION AND GENERAL REQUIREMENTS

1.1 GENERAL

These Technical Specifications are a part of the Contract documents specifying the technical requirements for the SFMTA light rail vehicle (LRV) procurement, LRV4. The provisions serve to define the design parameters and functional requirements for the LRVs.

This Technical Specification is meant to be a guide to prospective car builders that defines what is required for functionality. For systems and subsystems where there are no specification details, it is up to the Contractor to propose the most suitable equipment to integrate and operate in the SFMTA environment. In this manner, the Contractor has the flexibility to design LRV4 based on performance with the goal of providing SFMTA with a safe, effective, and reliable fleet with a lower overall cost. The Contractor is fully responsible for the design and integration of this LRV4.

Technical information provided by the SFMTA shall be for the Contractor's guidance and shall not be understood to be necessarily accurate and factual. The Contractor shall verify, inspect, test, or otherwise check the accuracy of information provided by the SFMTA as necessary to assure compliance.

Within this Technical Specification there are references to standards. This is not meant to limit the Contractor to the specific use of those standards, but to provide the Contractor with the minimum requirements of a given subject. Contractors may propose alternative standards and SFMTA will review those on a case by case basis. Contractors that choose to propose alternative standards must submit each request in writing with detailed information including differences between the standard specified and the proposed standard along with any benefit to SFMTA for accepting the alternative. Any requests for alternative standards should be submitted for acceptance during this RFP process.

In the various parts of the Contract Documents where reference is made to applicable codes and standards, the Work shall, except as otherwise specified, conform to the latest issue of the referenced code or standard available at the time the Work is delivered or performed. Upon any point of conflict between codes and standards applicable to the Work, SFMTA shall be notified, but the code or standard imposing the more or most stringent requirement as the case may be shall govern, unless otherwise stipulated by SFMTA in writing.

1.2 ABBREVIATIONS AND DEFINITIONS

1.2.1 Abbreviations

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

AAR	Association of American Railroads
ac	Alternating Current
ADA	Americans with Disabilities Act
ANSI	American National Standards Institute

APS	Auxiliary Power Supply
APTA	American Public Transit Association
AREA	American Railway Engineering Association
AREMA	American Railway Engineering and Maintenance Association
ARI	Air Conditioning and Refrigeration Institute
ASCII	American Standard Code for Information Interchange
ASHRAE	American Society of Heating, Refrigeration and Air Conditioning
ASIC	Application Specific Integrated Circuit
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
ATCS	Automatic Train Control System
ATP	Automatic Train Protection
AWG	American Wire Gauge
AWS	American Welding Society
BAFO	Best and Final Offer
BLS	Bureau of Labor Statistics
BOM	Bill of Materials
CAD/AVL	Computer-Aided Dispatch/Automatic Vehicle Location
CCTV	Closed Circuit Television
CCU	Communications Control Unit
CDRL	Contract Deliverables Requirements List
CEM	Crash Energy Management
CFR	Code of Federal Regulations
CPUC	California Public Utilities Commission
DB	Dry Bulb
dB	Decibels
dc	Direct Current
DIN	Deutsche Industrie Norm (German Industrial Standard)
DOT	United States Department of Transportation
DTE	Diagnostic and Test Equipment
DTEM	Diagnostic Test Equipment Manual
DVAS	Digital Voice Announcement System
EB	Emergency Brake
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
EN	European Standards Engineers
FAI	First Article Inspections
FCC	Federal Communications Commission
FDR	Final Design Review
FEA	Finite Elements Analysis
FMECA	Failure Mode Effect and Criticality Analysis
FRA	Federal Railroad Administration
FRACAS	Failure Reporting And Corrective Action System
FRP	Fiberglass Reinforced Plastic
FSB	Full Service Brake
FTA	Federal Transit Administration

GEBR	Guaranteed Emergency Brake Rate
GPS	Global Positioning System
HRM	Heavy Repair and Overhaul Manual
HSCB	High-Speed Circuit Breaker
HV	High Voltage
HVAC	Heating, Ventilation, and Air Conditioning
HVDC	High Voltage Direct Current
ICD	Interface Control Document
ICEA	Insulated Cable Engineers Association
ICP	Interface Control Plan
IEC	International Electro-technical Committee
IEEE	Institute of Electrical and Electronic Engineers
IPC	Illustrated Parts Catalog
IS	Integrated Schematic
ISO	International Organization for Standards
LAHT	Low Alloy High Tensile Strength (Steel)
LED	Light Emitting Diode
LLRU	Lowest Level Replacement Unit
LRU	Line Replacement Unit
LRV	Light Rail Vehicle
LV	Low Voltage
LVDN	Low Voltage Distribution Network
LVPS	Low Voltage Power Supply
MCWB	Mean Coincident Wet Bulb
MDBF	Mean Distance Between Failure
MDS	Monitoring and Diagnostics System
MIL	Military Specification
MSB	Maximum Service Brake
MTTR	Mean Time to Repair
NDT	Non-Destructive Test
NEC	National Electrical Code
NEMA	National Electrical Manufacturers Association
NFL	No Field Lubrication
NFPA	National Fire Protection Association
NTP	Notice to Proceed
OEM	Original Equipment Manufacturer
PA	Public Address
PIN	Personal Identification Number
PDR	Preliminary Design Review
PEI	Passenger Emergency Intercom
PIV	Peak Inverse Voltage
POE	Power Over Ethernet
PTE	Portable Test Equipment
PTU	Portable Test Unit
PVC	Polyvinyl Chloride

QA/QC	Quality Assurance/Quality Control
RFP	Request for Proposals
RMM	Running Maintenance Manual
RMS	Root Mean Square
RTM	Requirements Traceability Matrix
SAE	Society of Automotive Engineers
SFMTA	San Francisco Municipal Transportation Agency,
SSPP	System Safety Program Plan
t	Time
TIG	Tungsten Inert Gas
TWC	Train to Wayside Communications
UL	Underwriters Laboratories, Inc.
UMTA	Obsolete reference for FTA predecessor organization
v	Velocity
VAC	Volts – Alternating Current
VDC	Volts – Direct Current
VHB	Vehicle History Book
WB	Wet Bulb
WLAN	Wireless Local Area Network

1.2.2 Definitions (Terms)

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

A End – One end of the vehicle shall be designated the A end. This end shall carry the pantograph. The opposite end of the vehicle shall be designated the B end.

A Section – The section of an articulated vehicle at the A end.

Active Cab – The controlling light rail vehicle cab in a train.

ADA - 49 CFR, Part 38, Americans with Disabilities Act (ADA) Accessibility Specifications for Transportation Vehicles.

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

Agreement (Contract) – The negotiated written agreement executed by SFMTA and the Contractor in conformance with the Contract Documents for the performance of the Work which incorporates and includes the remaining Contract Documents.

Alteration – A change or substitution in the form, character or detail of the work done or to be done within the original scope of the Contract.

Approved or Approved Type – Design, type material, procedure, or method given acceptance by the SFMTA.

Assembly – A collection of subassemblies and components typically performing a variety of functions within the context of a larger system. Examples of assemblies are trucks, electronic control units, air compressors, etc.

Auxiliary Equipment – Any mechanism or structure, other than the vehicle body, traction motor, or propulsion equipment gearing, that performs a function at any time during the operation of the LRV, such as the heating and cooling subsystem, pumps, auxiliary inverter, vehicle door mechanism, air compressor, or light rail vehicle lighting.

Average Brake Rate (V/t) – The speed (V) at which brake force, as measured by motor current or brake cylinder pressure, has ramped up to its full service level, divided by the elapsed time (T) required to go from that speed to a lower speed.

Average Deceleration Rate – The ratio of the light rail vehicle speed at which braking effort achieves the commanded value and the elapsed time from that occurrence to zero vehicle speed. The elapsed time does not include braking effort build up time during jerk limiting and does not include operator reaction time or allowable dead time.

AW0 – Weight of empty ready-to-run vehicle.

AW1 – AW0 plus full seated load, including crew.

AW2 – AW1 plus standees at 4 passengers/M^2

AW3 – AW1 plus standees at 6 passengers/M^2.

B Section – the section of an articulated vehicle at the B end.

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.

Braking Effort – Retarding force developed by the propulsion subsystem, braking subsystem, or a combination of both subsystems.

Burn-In – Operating a component, system, or device in a test mode, often in an extreme or cycled temperature environment, for a specified period of time or distance, to confirm reliable operation.

Car – SFMTA Light Rail Vehicles, also referred to as "LRV4's" and "vehicles."

Car Stop – Street level stops, mainly at intersections where passengers may board and alight trains.

Catenary – Overhead power supply consisting of a combination of conductors and other hardware suspended above the tracks by means of cantilevers and wayside structures.

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

Compatibility – The condition where vehicle performance and control are operationally identical between two or more vehicles. Compatibility will allow multiple vehicles to couple together, with control of systems on all vehicles being effected by any lead vehicle of the consist.

Component – Portions of equipment not typically repaired or disassembled, such as nuts, bolts, resistors, fittings, single-piece castings. Used interchangeably with "parts".

Console – The control panel located in the cab of a light rail vehicle directly in front of the operator's seat.

Contact Line – A system that conducts electric power between the wayside and a vehicle. Can consist of third rail, catenary, or trolley wire.

Contract Drawings – Drawings provided by the SFMTA as part of this procurement.

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.

Coupler – A device for mechanically coupling light rail vehicles together. This term is also applied to connectors, as in "electric coupler" and "pneumatic coupler."

Critical Path – In a production schedule, a sequence of stages toward the achievement of a final task that accounts for all other tasks that must be completed in order to accomplish the final task.

Deadman Feature – A device designed to detect a lack of attention or disability of an operator and to automatically apply full-service braking when it detects such lack of attention or disability.

Design Life – The period of time for which the light rail vehicle is intended to be safely and reliably usable for its original purpose.

Draft Gear – The resilient portion of the coupler device that cushions buff and draft forces transmitted between coupled vehicles.

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 tractive effort.

Dwell – The period of time from the instant a train stops at a station until the instant the train resumes moving.

Dynamic Braking – Braking which is not part of the friction braking system and is instead produced by the Drive.

Electric Braking – A type of Dynamic Braking in which the power generated by the traction motors, when driven as generators, is either regenerative or is dissipated in resistor banks.

Emergency Stop – The stopping of a light rail vehicle or train by an emergency brake application. Once initiated, the emergency brake application cannot be released until the light rail vehicle or train has stopped.

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

Failsafe – A design principle of a system or hardware configuration that ensures that a failure shall not result in an unsafe condition.

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

Failure Reporting And Corrective Action System – A system that will record all failures during production, functional testing (at the Contractors Facilities and on-site at SFMTA), identify the systematic failure data collection, management, analysis, and corrective action implementation.

Failure, Service – Any failure that prevents a vehicle from being placed into service or from completing a trip as scheduled.

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

First Article – The first item produced that conforms and defines all subsequent production items. First articles are intended for review by the SFMTA.

Form, Fit and Function – The physical attributes of a device that allow the device to be used in place of another device due to similarities of general shape (outline, clearances), mounting arrangement (footprint), and operation (inputs/outputs) of the device.

Full Service Braking – The maximum braking effort employed to stop a light rail vehicle in the absence of an emergency stop signal.

Gauge, Track – The distance between the inside face of rails, usually measured $^{5}/_{8}$-inch below the top of the centerline of heads of running rails and at a right angle thereto.

Headway – The time separation between two trains, both traveling in the same direction on the same track, that is measured from the time the front end of the leading train passes a given reference point to the time the front end of the train immediately following passes the same reference point.

High Voltage – See Primary Power.

Indicated – As presented in this document.

Inspector – The person or firm designated by the SFMTA as its quality control representative.

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

Interface Control Plan – Contractor provided plan that will identify all vehicle to wayside interfaces, validate the accuracy of the interface, and document how the design accommodates all interfaces.

Interlock – A condition whereby one function is dependent on the operation of another function.

Irretrievable – Describes an application of the brakes that cannot be released until the train is at zero speed.

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

Lead Vehicle – In the direction of travel, the forward-most light rail vehicle of the train.

Left Hand – Left side of the light rail vehicle when one is facing the windshield of the “A” end of the vehicle from inside the vehicle.

Light – The transparent portion of a window.

Line Replaceable Unit (LRU) – A component of a system that when failed or in need of repair, is intended to be exchanged and repaired off of the vehicle. The exchange, including removal of one component and installation of its replacement, is designed to be accomplished within one working shift.

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

Load Weighing – The measurement of total passenger weight for the purpose of adjusting tractive effort to produce a constant acceleration or braking rate.

LRT System (MUNI Metro System)– SFMTA's light rail transit infrastructure, facilities, systems, services, and vehicles dedicated to public transportation within the SFMTA's geographical territory.

Maintainability – The degree to which any system or equipment can be rapidly, easily, effectively, and properly maintained.

Manufacturer – The builder or producer supplying materials, equipment, or apparatus for installation on the car.

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 Distance Between Component Failures (MDBCF) – The mean operating mileage between independent failures of a component.

Mean Distance Between Service Failures (MDBSF) – The mean operating mileage between independent service failures.

Mean Distance Between Train Delays (MDBTD) – The mean operating mileage between train delays caused by equipment or system failures.

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

Mission Profile – An analysis of the operating environment of the LRV to include environmental conditions (in tunnel and surface - averages and extremes), operating mileage, operating hours, duty cycles, and time factor utilization. The Mission Profile is used for Reliability predictions and analysis.

No Motion – The vehicle speed at or below the lowest speed detectable by the vehicle control systems.

Operator – The individual onboard who is responsible for the light rail vehicle and train operation.

Pantograph – A device used for current collection from an overhead contact line. It consists of a dual-strip electrical collection shoe carried by a collapsible and adjustable frame.

Part – See component, above.

Performance – The measure of output or results obtained by a component, system, person, team, etc., as specified in the Contract Documents.

Primary Power – The unconditioned electric power that enters the propulsion system, either from external current collection means or from an on-board prime mover.

Procurement – The furnishing of all the items, materials, equipment, data, design, services, management, labor, and incidentals specified or otherwise necessary for timely and properly designing, manufacturing, delivering, and testing the LRVs or otherwise completing the Work.

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

SFMTA Supplied Equipment – Equipment furnished by the SFMTA to the Contractor for installation in or on an LRV.

Recovery Time – The time required for a system or condition to return to its original state (or some stated percentage of its original value) after being disrupted or destabilized.

Redundancy – The existence in a system of more than one means of accomplishing a given function.

Regenerative Braking – Electric braking where the power generated by the traction motors, when driven as generators or alternators, is conditioned and returned to the contact line or on-board energy storage.

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

Revenue Service – The provision of transportation services to the SFMTA's customers.

Right Hand – Right side of the light rail vehicle when one is facing the windshield of the "A" end of the vehicle from inside the vehicle.

Service – As in Service Use, Service Braking. The operation of the cars under normal conditions.

Service Proven Design – Any component, system, or subsystem that has a proven history of successful operation in revenue service similar to that of the LRV System. Proof of successful operation shall be substantiated by submission of reliability/failure data, service time and location, modification information, and maintenance records as required by the Contract Documents.

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

Slip, Wheel – While tractive effort is applied, the condition when the rotational speed of the wheel is greater than that for pure rolling contact between tread and rail.

Spare Parts – Components supplied by the Contractor to the SFMTA intended for use in maintenance or repair of vehicles.

Speed, Balancing – The speed attained by the vehicle or train when resisting forces exactly equal applied tractive forces.

Speed, Base – The speed to which the maximum constant acceleration can be maintained at the nominal line voltage or rated prime mover output.

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 – see Slip, Wheel.

Start-Up Spare Parts – Spare parts provided by the Contractor to support the LRVs first delivered to SFMTA.

Station Stops – Locations identified on SFMTA's MUNI Metro System Maps where passengers board and alight trains during revenue service. Also see Car Stop.

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.

Subassembly – A collection of components used to perform a distinct function, usually in conjunction with other subassemblies and components, as part of a larger system. Subassemblies are usually replaceable as units, such as circuit boards, bearings, and valves.

Superelevation – On a curve, the vertical distance, measured in inches that the outer rail is above the inner rail.

Technical Provisions - see Technical Specifications as defined in the Agreement.

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

Time Constant – Slope of curve in units of controlled variable per unit of time, measured during the buildup time interval.

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, 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, Down – The time during which equipment is not capable of doing useful work because of maladjustment, malfunction, or maintenance in progress.

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 application of power to an operable device until it is capable of performing its intended function.

Traction System – The system of wheels, motors, gears, brakes, direct controls, and appurtenances that propels or retards a car in response to control signals.

Tractive Effort – The horizontal force that is measured at the wheel-rail interface.

Train – Any number of vehicles, from one to four, coupled together and moving as one.

Trainline – The means of sending a signal to all light rail vehicles in a consist via a continuous electrical or pneumatic circuit connected through appropriate coupling devices.

Tram – Short form referring to trammel point inspection of truck frames for squareness. "In tram" is the condition of ideal truck geometry in which the axles are perfectly parallel and the wheels longitudinally in perfect 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 single operating unit, which may consist of one or more sections.

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

Warm Up Time – The elapsed time from application of power to an operable device until it is capable of performing its intended function.

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.

1.3 UNITS OF MEASURE

A	- Ampere
Btu	- British Thermal Unit
dB	- Decibel
dBA	- Decibel on the 'A' weighted scale
ft	- Foot
ft^3/min	- Cubic Feet per Minute
g	- Acceleration due to Gravity (32.2 ft/s^2)
h	- Hour
Hz	- Hertz
in	- Inch
J	- Joule
kg	- Kilogram
kWh	- Kilowatt hour
lb	- Pound
lbf	- Pound force
mph	- Miles per hour
mphps	- Miles per hour per second
mphpsps	- Miles per hour per second per second
min	- Minute
mV	- Millivolt
µV	- Microvolt
N	- Newton
oz	- Ounce
psi	- Pounds force per square inch
s	- Second
V	- Volt
°C	- Degrees Celsius
°F	- Degrees Fahrenheit

1.4 DESCRIPTION OF WORK

1.4.1 General

The Work shall include the designing, manufacturing, testing, furnishing, delivery, and performance testing of New LRVs. The Work shall also include delivery of data, manuals, drawings, training and support services, spare parts, special tools, and test equipment which shall be delivered as specified in the Contract Documents. Contractor may deviate from these requirements only with specific approval of the SFMTA.

1. Contractor Responsibilities:

a. 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.
b. The Contractor is responsible for the selection, application, and integration of equipment and materials as necessary to conform to specified requirements.
c. 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 the SFMTA on a case-by-case basis, and all restorations shall be performed by the original equipment manufacturer.
d. The Contractor shall be responsible for becoming familiar with the SFMTA's LRT System. The SFMTA will make available for review existing information upon request at a mutually convenient time and place.
e. The Contractor shall ensure the LRV4 accommodates all existing conditions on the SFMTA system, whether or not they are defined in this specification. During the design phase the Contractor shall be responsible for validating all interfaces between the LRV and its subsystems with all wayside elements through an Interface Control Plan (ICP) that will identify all interfaces, validation that the wayside interface is accurate, and documenting how the Contractor is addressing each interface throughout the entire design phase.

1.4.2 Infrastructure Description

1. The LRV shall operate safely on the infrastructure used by the SFMTA. The characteristics of this infrastructure are provided in Section 2 of this Specification. In addition, the Contractor shall be responsible for becoming familiar with the SFMTA's LRT System, and the Contractor bears the responsibility for confirming the correctness of the detailed system information described in this specification as it relates to the Contractor's design.

1.4.3 Performance

The LRV shall meet the performance requirements of the SFMTA which are contained in this Specification. The Contractor's test plan shall include elements that demonstrate the ability of the vehicle to meet the performance requirements of the SFMTA.

1.4.4 Compatibility

The vehicle shall be fully compatible with SFMTA's existing infrastructure, including maintenance facilities. Mechanical compatibility with the existing LRV2/3 vehicle fleet is also required as described in these specifications. The Contractor shall provide an interoperability and compatibility report describing the compatibility of the LRV4 with the existing LRVs and the wayside/facilities elements.

1.4.5 Quality

Manufacturing, quality control and quality assurance shall be equivalent to the requirements set forth in Section 19, Materials & Workmanship. The workshop practices and manufacturing control procedures shall produce a product quality consistent with the installation, assembly and part drawings.

1.5 HUMAN ENGINEERING

The car design shall take into consideration the human factors engineering of the U.S. adult population anthropomorphic data and be based on human factors engineering, with the range of people from the 2.5 percentile female to the 97.5 percentile male as defined by “The Measure of Man & Woman”.

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2 DESIGN AND PERFORMANCE CRITERIA

2.1 GENERAL DESIGN REQUIREMENTS

1. Contractor shall design and manufacture the LRV to operate successfully within the SFMTA's environment as described herein.
2. Subject to the Contractor's recommended maintenance practices and normal industry accepted operating procedures; Contractor shall design the LRVs for the following normal revenue service characteristics in the SFMTA's environment:
    a. A Maximum Revenue Service Speed (MRSS) of 50 mph,
    b. A minimum service life of 25 years,
    c. Annual average mileage of 40,000 miles per vehicle.
3. Life cycle costs are of the utmost importance to SFMTA. Therefore Contractor shall design the LRV to minimize such costs by focusing on reliability, ease and quantity of preventive maintenance, ease of corrective maintenance, low weight and low overall energy consumption.

2.2 GENERAL VEHICLE CONFIGURATION

2.2.1 General Characteristics

1. The car body shall have multiple sections, joined by articulations.
2. The vehicle shall be of a high floor design, with provision for both high and low level boarding.
3. The vehicle shall be equipped with sufficient passenger doorways to minimize load/ unload times, consistent with the existing fleet (which has four doorways per side), and minimize station dwell times.
4. The vehicle shall feature a fully equipped operator's cab on each end of the vehicle.
5. The vehicle shall feature equal operation, control, and performance in both directions.
6. The vehicle shall be capable of normal multiple unit operation in consists of up to four LRVs, and in emergency towing situations, consists of up to eight LRVs.

2.2.2 Seating Arrangement

1. The predominant seating arrangement shall be transverse, bi-directional, knee-to-back, and four abreast (2 plus 2) unless otherwise accepted by SFMTA.
2. A minimum aisle width of 32 inches between transverse seats and continuously from one end of the car to the other end shall be provided.
3. A minimum of 60 passenger seats per LRV is desired; however passenger capacity and flow for boarding and alighting should take precedence.

2.2.3 Elderly and Disabled Accessibility

1. Space shall be provided in each end of the vehicle, immediately adjacent to the side doors to accommodate at least two wheelchairs per end (four spaces per vehicle).

Because of infrastructure constraints, the existing locations cannot change and shall be in each end of the vehicle, adjacent to the end door closest to the cab.

2. Flip down seats may be provided in wheelchair areas to provide additional seating capacity when the areas are not in use

2.2.4 Identification

1. The numbering scheme shall utilize four-digit numbers as specified by the SFMTA.

2.2.5 Critical Vehicle Dimensions

2.2.5.1 Car Body Dimensions

1. Length of car shall be not greater than 75 feet over coupler faces.
2. Width of car shall be as wide as possible consistent with the structural constraints of the SFMTA system.
3. Height of car (including locked down pantograph) shall be not greater than 11 feet 6 inches.

2.2.5.2 Pantograph Dimensions

1. The minimum pantograph operating height, at any car weight and any condition of wheel wear, shall be 12 feet 2 inches.
2. The maximum pantograph operating height, at any car weight and any condition of wheel wear, shall be not less than 19 feet.
3. The pantograph head shall be sized to maintain contact without dewirement under all conditions of wire stagger and offset and vehicle throw due to curvature and sway due to roll.

2.2.5.3 Wheel Dimensions

1. The wheel tread profile shall be optimized by the Contractor to minimize derailment risk, noise and wear, and to maximize wheel life and truing interval, while operating on the SFMTA infrastructure.

2.2.5.4 Truck Dimensions

1. The truck spacing, centerline to centerline, shall be 24 feet and consistent with SFMTA's maintenance facilities layouts for jacking and lifting.

2.2.6 Clearance Requirements

2.2.6.1 General

1. Vertical undercar clearance shall be at least 2 in from top of rail with the maximum suspension deflection and Car Body roll, minimum vertical curve radius, and fully worn wheels.
2. Clearances between truck components and the Car Body shall be sufficient to avoid contact under all normal and degraded operating conditions.

2.2.6.2 Dynamic Envelope

1. The dynamic envelope and swept path of the vehicle shall be based on that shown in the Contract Drawings for all normal operating conditions and certain abnormal conditions which could include a reasonable combination of failed suspension elements. However the Contractor is required to verify existing conditions to ensure worst case conditions are identified and addressed in the design of the LRV, including actual clearance conditions. If the Contractor wishes to use a larger envelope, then responsibility for validation of such an envelope shall rest with the Contractor.

2.2.6.3 Station Platform Interface

1. The LRV shall provide ADA compliant level boarding at high level platforms (new vehicle/new station requirements will apply) and shall provide ergonomically appropriate stepping from low level platforms to the car floor.
2. Station platform heights on the SFMTA system are nominally 34 inches above top of rail for high platform stations, and at varying elevations of sidewalk height elsewhere, with platform edges of high level platforms at a nominal 56 inches from track centerline.
3. Station platforms occur on both curved and graded track. There is one non-tangent high platform, at Castro Station, and the steepest stop is 9%.
4. There are high-blocks at the leading ends of some low level stations, for wheelchair access. Doorways shall be compatible with wheelchair access at such stations.
5. An LRV mounted between car barrier system shall be provided to comply with ADA requirements at high level station platforms.

2.2.7 Weight and Passenger Loading

1. The maximum desired AW0 vehicle weight shall be 76,000 pounds.
2. The maximum AW3 vehicle weight shall be 110,000 pounds. All equipment shall be arranged so that its weight is distributed to maximize adhesion and minimize the propensity to derail.
3. Moveable steps may be considered when calculating passenger loading.

2.3 OPERATING ENVIRONMENT

2.3.1 Right-of-Way Description

1. See Appendix A for a System Description and the Contract Drawings of the SFMTA's operating right-of-way. SFMTA will provide the Contractor with SFMTA track maintenance standards and route profile. However, the Contractor is required to verify existing conditions to ensure worst case conditions are identified and addressed in the design of the LRV, including actual track conditions.

2.3.2 Vehicle Dynamic Analysis

1. The Contractor shall demonstrate the performance of the vehicle for safety against derailment during low speed curving, and freedom from truck hunting at all operating speeds.

2.3.3 Climatic Conditions

2.3.3.1 Vehicle Operational Climate Conditions

1. The vehicle shall be capable of full operational functionality and performance in the SFMTA's operating climate, defined by the normal and expected climatic design information for the City of San Francisco contained within the latest edition of the ASHRAE Handbook.
2. The vehicle shall be suitable for operation in the presence of normal and expected amounts of sand, dust, trash, and leaf accumulation on the streets and rights of way in the SFMTA's operating environment.

2.3.3.2 HVAC Design Conditions

1. The acceptable interior Temperature range for the vehicle is 72 degrees Fahrenheit to 78 degrees Fahrenheit, for ambient temperatures 95 degrees Fahrenheit and below.
2. For ambient temperatures above 95 degrees Fahrenheit, the LRV interior temperature shall be kept to 20 degrees Fahrenheit less than ambient.
3. The HVAC system shall be designed to maintain the above interior temperatures, while the vehicle is subjected to the following ambient environmental conditions as specified in the Climatic Design Information chapter of the latest edition of the ASHRAE Handbook.
   a. Minimum ambient dry bulb temperature (Extreme Annual DB, Mean, Max),
   b. Maximum ambient dry bulb temperature (Extreme Annual DB, Mean, Min),
   c. Cooling design dry bulb and coincident wet bulb temperatures (Cooling DB/MCWB, 1%),
   d. Heating design dry bulb temperature (Heating DB, 99%).
4. The HVAC system shall also be subjected to the following design conditions:
   a. The passenger loading shall be taken at the AW2 condition, at 450 BTU/hr (132 Watts) per passenger at 50% sensible heat ratio (cooling),
   b. Fresh airflow to the car shall be a minimum of 5.0 ft^3/min/passenger,
   c. The solar load shall be per ASHRAE recommendations,
   d. Interior relative humidity shall be 50% maximum.
5. The heating capacity shall be sufficient to raise the fresh air temperature from the winter design day ambient temperature to the required interior temperature as stated within 30 minutes.
6. The cooling capacity shall be sufficient to lower the fresh air temperature from the summer design day ambient temperature to the required interior temperature as stated within 30 minutes.

2.3.4 Fordability

1. With maximum wheel wear, the LRV shall operate without damage or equipment malfunction in water up to 3 in above the top of rail, at speeds up to 10 mph.
2. A stationary vehicle, not connected to line power, shall not be damaged by water levels up to 6 in above top of rail.

2.3.5 Supply Voltages

1. Unless otherwise specified, rated performance and full functionality shall be delivered at any voltage between nominal and maximum voltages.
2. All equipment on the vehicle shall be self-protected from damage and improper operation due to:
    a. High-voltage transients across the supply terminals of that equipment,
    b. High-voltage transients impressed between either supply terminal and the vehicle body, and
    c. Long-term over-voltage and under-voltage conditions resulting from other equipment failure modes.

2.3.6 Wayside Power Supply

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

2.3.7 Low Voltage Power System

1. Where circuits are powered through trainlines, powered apparatus shall function satisfactorily in all vehicles, including the last vehicle of a maximum train, with the trainlines powered from the low voltage power system of the lead vehicle.

2.4 PERFORMANCE REQUIREMENTS

2.4.1 General

1. The following establishes the performance required of the LRV, whether in a single vehicle consist or multiple unit consist of up to the maximum specified length, and of similar or dissimilar weights, as specified below.

2.4.2 Propulsion and Braking Assumptions

1. All specified acceleration, braking and jerk rate requirements are based on level tangent dry track in still air except as otherwise noted.
2. All specified performance capabilities shall be provided over the full-specified range of the following:
    a. Wheel wear,
    b. Ambient temperatures.

2.4.3 Contact Line Voltage Range

1. Vehicle equipment shall be designed and tested for operation at nominal 600 VDC power, but normal voltage variations and power isolation gaps shall not cause damage.
2. Line voltage ranges from 450 VDC to 750 VDC, with occasional voltage spikes of 1,800 volts peak with a duration of 30 milliseconds.
3. All equipment shall be designed for required performance provided down to 575 VDC supply voltage. Performance may be degraded between 575 and 450 VDC.

4. Above 575 VDC, the tractive effort versus speed characteristic shall not vary as a function of catenary voltage.
5. Full specified dynamic braking rates shall be available at the nominal or higher catenary voltage during regenerative braking.
6. Once dynamic brake is initiated, full specified dynamic braking rates shall be available whenever catenary is not receptive and with no catenary voltage present.
7. For line voltages outside the normal 450-750 VDC limits, equipment may be designed to shut down or operate at modified performance levels.

2.4.4 Acceleration Requirements

1. The vehicle shall provide acceleration capabilities on level tangent track as follows:
    a. Full acceleration average rate at master controller maximum power position of 3.0 mphps ± 5% at all vehicle weights from AW0 to AW2, and shall be available to at least 20 mph. At loads greater than AW2, tractive effort shall be held at the AW2 level.
    b. From a standing start, time to reach 50 mph shall not exceed 35 s, at AW2 loading.
    c. In addition, from zero speed, the vehicle shall travel a minimum of 600 feet in 20 seconds.
    d. These times shall be measured from change in trainline signals to the propulsion equipment.

2.4.5 Speed Requirements

1. The maximum design speed of the vehicle shall be 55 mph with all conditions of wheel wear.
2. Actual operating speed shall be limited to 52 mph by over-speed protection.

2.4.6 Service Brake Requirements

1. The full service brake (FSB) for all vehicle weights up to AW3 and speeds from 50 mph to 0 mph shall provide an average retardation rate of 3.5 mphps +/- 5%, with a maximum rate of 4.0 mphps and a minimum rate of 3.0 mphps.
2. Braking rates shall also be in compliance with CPUC GO143B.

2.4.7 Emergency Braking Requirements

1. Release of the Deadman Handle shall cause a Full Service Brake application.
2. Application of Emergency Braking (EB) shall be available by actuating the console EB push button switch, or the Emergency brake position on the Master Controller.
3. EB is considered a safety system. The friction brake system (disc only) shall have the capability of producing at least one stop from maximum service speed under AW3 loading in case of dynamic brake failure.
4. A Guaranteed Emergency Brake Rate (GEBR) is required by ATCS system. See Section 14 Automatic Train Control for details.

5. For EB brake entry speeds below 30 mph the average deceleration rate shall be a minimum of 5.0 mphps.
6. Braking rates shall also be in compliance with CPUC GO143B.
7. The following adhesion levels are provided as information only and the Contractor should verify by field testing to determine actual adhesion levels. It is anticipated that in tunnels, an adhesion level of 16% can be achieved and that elsewhere the adhesion level may be lower than 11.4%.

2.4.8 Wheel Spin/Slide Correction

1. A system shall be provided to detect and correct wheel spin and slide on each vehicle whether random or synchronous on an individual truck basis, both in acceleration and braking.
2. 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.
3. The spin/slide system shall be functional under all acceleration and all dynamic and disc braking commands except for emergency brake applications initiated by the console EB pushbutton switch.
4. The spin/slide system shall comply with CPUC GO143B.

2.4.9 Jerk Limits

1. In response to a step input command signal, the average rate of change of actual acceleration or deceleration, after any mode change dead time, shall be between 2.0 mphpsps and 3.0 mphpsps.
2. Emergency brake applications shall not be jerk limited.

2.4.10 Parking Brake

1. The parking brake system shall be capable of holding a vehicle at all weights up to AW3 on a 9% grade indefinitely.
2. The parking brake system shall comply with CPUC GO143B.

2.4.11 Duty Cycle Rating

1. The vehicle shall be capable of continuous operation on any SFMTA route without exceeding the continuous rating of any equipment, under the following conditions:
    a. A constant AW2 load,
    b. A dwell time of 15 s at each stop,
    c. Acceleration and braking at maximum service rates,
    d. Operation to and maintenance of maximum track speeds,
    e. A one minute layover at each end of the line.
2. In addition, a train with an AW3 load shall be capable of pushing or towing another unpowered, unbraked train of equal length with an AW3 load from the point of equipment failure to the next stop, and then at AW0 load to the end of the line in the

original direction of travel, at reduced speeds, without damage or reduction in equipment life.

3. The vehicle shall be capable of operating at speeds of 5 mph or less continuously at AW2 on any portion of the SFMTA's line, without overheating or damage to the vehicle.

2.5 NOISE, VIBRATION, RIDE QUALITY

2.5.1 General

1. Unless otherwise indicated, noise level (as defined by the latest version of ANSI S1.4) is the weighted sound pressure level measured by the use of a metering characteristic and weighing A, B, or C as specified in ANSI S1.4. The unit of noise level is decibels (dB), and the reference pressure is 20 micropascals.

2.5.2 Pure Tones

1. The maximum allowable noise level shall be reduced by at least 3 dB if significant pure tones in the range from 250 Hz to 4,000 Hz are present in the noise.
2. Pure tone noise shall be considered significant in this context if any one-third octave band sound pressure level is 5 dB, or more, higher than the arithmetic average of the 2 adjacent bands containing no pure tones.

2.5.3 Interior Noise

1. The vehicle shall meet the following interior noise level as measured in an open section:
   a. With the vehicle stationary with windows and doors closed, with all auxiliary equipment operating simultaneously under normal operating conditions, the interior noise level shall not exceed 72 dBA.
   b. With the vehicle stationary and any one system of equipment operating at normal conditions, the vehicle interior noise shall not exceed 68 dBA.
   c. With the vehicle operating on the SFMTA's system, on non-corrugated, appropriately lubricated rail, at any speed up to the maximum permitted, in any curve down to 45 ft radius, and under any acceleration or deceleration condition, interior noise shall not exceed 78 dBA.

2.5.4 Wayside Noise Limits

1. The measurement shall be taken at a distance of 50 ft from the centerline of the track, 5 ft the above ground.
2. Average noise levels emanating from the vehicle shall not exceed the following levels with all auxiliary equipment operating simultaneously:
   a. Vehicle stationary, empty: 68 dBA,
   b. Vehicle empty, on tangent track in motion under all conditions of speed and acceleration or braking: 75 dBA.

2.5.5 Ground Borne Vibration

1. Ground borne vibration has been a significant problem in San Francisco in the past. The LRV4 shall have a ground borne vibration signature which is better than that exhibited by the LRV2 with comparable track, loading, suspension and speed conditions. This shall be demonstrated by the Contractor by analysis and test.

2.5.6 Vibration Generation

1. Equipment and auxiliaries mounted anywhere on the vehicle, Car Body, or trucks shall not cause objectionable vibrations anywhere on the vehicle floor, walls, ceiling panels and seat frames.

2.5.7 Vibration and Impact Loads

1. All vehicle equipment shall operate without damage or degradation of performance when subjected to vibration and impacts encountered during normal service, and shall be compliant with and tested per IEC 61373 standard, including all functional and durability requirements.

2.5.8 Ride Quality

1. Ride quality shall be equal to, or better than, that provided by an LRV2/3 vehicle, which is equipped with new suspension and newly trued wheels.
2. Ride quality shall be evaluated for all load conditions AW0 to AW3, and all normal vehicle acceleration, deceleration, and speed conditions on comparable quality track.

2.5.9 Curving and Derailment Safety

1. The LRV shall curve smoothly and have low risk of derailment under conditions of new wheel/new rail and worn wheel/worn rail.
2. Analysis and test shall be used to demonstrate that, for all conditions within SFMTA's accepted condemning limits for wheel and rail:
    a. Single wheel L/V, measuring the resistance to wheel climb derailment, shall not exceed the Nadal limit for the effective flange angle of the wheel/rail pair with a wheel/rail coefficient of friction of 0.5.
    b. Minimum Vertical Wheel Force, to prevent wheel unloading, shall be greater than 10% of the static wheel load.
    c. Net Axle Lateral force (NAL), as a check on track panel shift, shall be less than one-half the static vertical axle load for AW0 and AW3.

2.5.10 Stability

1. The contractor shall analyze vehicle stability in tangent track at speeds up to 110% of maximum revenue service speed, for worst case combinations of worn wheel and rail (within SFMTA condemning limits). The output of lateral accelerations from transducers on the truck frame shall be reported to indicate if truck hunting occurred. Hunting shall be defined as six or more consecutive oscillations where truck frame lateral accelerations exceed 0.8g peak-to-peak. Hunting shall not occur up to

maximum revenue service speed. Tangent track segments in the model shall be at least 2000 ft long.

2.6 ELECTROMAGNETIC INTERFERENCE AND COMPATIBILITY

2.6.1 General

1. The Contractor shall design and construct the vehicle such that its equipment does not electrically interfere with the safe and proper operation of the vehicle itself or any wayside equipment, including signaling and communications equipment or systems external to the LRT system. Refer to IEEE Standard 16 for general electromagnetic compatibility requirements. The Contractor shall be fully responsible to survey the existing SFMTA system to confirm the acceptability of these limits on the new vehicles.
2. The Current LRV uses the following frequencies to communicate over the loop cable:
    a. A frequency of 36 kHz with a frequency shift of +/-400 Hz.
    b. A frequency of 56 kHz with a frequency shift of +/-200 Hz.
3. It is possible that the system could be upgraded to use IEEE 802.11 (WLAN) 2.4 GHz or 5GHz bands in the future.

2.6.2 EMC Plan

1. The Contractor shall develop an EMC Plan (EMCP) in accordance with APTA SS-E-010-98 identifying how the Contractor will achieve electromagnetic compatibility through its organization, activities, schedule, qualifications of staff, procedures and methods.

2.6.3 Field Conducted Emission Limit and Test

1. The contractor shall develop a Conducted EMI Test Procedure and perform a Field Conducted EMI Test based on UMTA-MA-06-0153-85-6.
2. The test procedure shall include worst-case conditions including SFMTA worst case track circuits.

2.6.4 Field Inductive Emission Limit and Test

1. The Contractor shall develop an Inductive EMI Test Procedure and perform a Field Inductive EMI Test based on UMTA-MA-06-0153-85-8.

2.6.5 Field Radiated Emission Limit and Test

1. The Contractor shall develop a Radiated EMI Test Procedure and perform a Field Radiated EMI Test based on UMTA-MA-06-0153-85-11.

2.6.6 Field Radio Frequency Immunity Test

1. The Contractor shall develop a Field Radio Frequency Immunity Test Procedure and perform a Field Radio Frequency Immunity EMI Test.

2. Radio Frequency emitting devices include handheld radios typically used by SFMTA and cell phones typically used by passengers to demonstrate immunity of the train equipment operation under test and the emitting device shall be six (6) inches.

2.6.7 Reports

1. The Contractor shall provide reports for all testing from Sections 2.6.3, 2.6.4, 2.6.5, and 2.6.6.

2.7 SERVICE-PROVEN DESIGN

1. Vehicle subsystem equipment shall be service proven in a rail transit environment, unless otherwise approved by the SFMTA.
2. In general, a service-proven design will meet all the following criteria:
   a. In revenue rail operation for at least 2 years,
   b. Used in revenue rail operation for at least 1 million vehicle miles with at least 50,000 miles per vehicle,
   c. Has a minimum fleet size of 20 vehicles,
   d. Has achieved a level of reliability consistent with the requirements in this Specification.

2.8 RELIABILITY

2.8.1 General

1. Contractor shall design each component, assembly, subsystem, and system element in a manner such that it will perform its function under the specified design operating conditions without failure for the durations specified. The Contractor shall demonstrate the Mean Distance Between Component Failure (MDBCF) and Mean Distance Between (chargeable) Train Delays (MDBTD) for its vehicle design, considering all failure modes for each component, assembly, subsystem, and system element. The combination shall result in realization of a fleet vehicle MDBTD of 25,000 miles.
2. The Contractor shall define the quantitative reliability of the overall vehicle and the vehicles' major systems. That definition shall maximize vehicle availability while minimizing vehicle overall life cycle costs. The data shall be provided for each major vehicle system and for the overall LRV. For systems requiring significant non-mileage related duty/loading, SFMTA will consider modifying the average speed factors for certain items, as demonstrated through a Contractor generated “Car Mission Profile Analysis," which would be subject to acceptance.
3. For this analysis, vehicle system reliability calculations shall be based on single vehicle operation with an average speed of 13 mph and an average of 40,000 miles per vehicle per year. For time operated equipment, a utilization factor will be developed through the mission profile to apply to equipment that is functioning when the vehicle is not accumulating mileage.
4. A Train Delay is defined as an incident causing a revenue train to be:
   a. More than five minutes late at its destination terminal;

    b. Canceled either at its original terminal or en route; or
    c. Rerouted.
5. A chargeable failure is defined as any failure that requires repair or replacement of any subsystem or vehicle component. Chargeable failures shall include intermittent, unverified and software failures which occur more than three times on a specific vehicle. The time, place or type of service in which the car was being operated at the time of a failure shall not be of any consequence. Failures outside of the control of the Contractor are excluded.
6. Mean Distance Between Component Failures shall be as follows:
    a. Traction Equipment & Controls shall have an MDBCF of 50,000 miles.
    b. Friction Braking shall have an MDBCF of 50,000 miles.
    c. Communications equipment shall have an MDBCF of 75,000 miles.
    d. Side Doors and Control equipment shall have an MDBCF of 85,000 miles.
    e. Lighting equipment shall have an MDBCF of 350,000 miles.
    f. Auxiliary Electrical Apparatus shall have an MDBCF of 100,000 miles.
    g. HVAC equipment shall have an MDBCF of 100,000 miles.
    h. Couplers and Draft Gear shall have an MDBCF of 100,000 miles.
    i. Trucks and Suspension shall have an MDBCF of 170,000 miles.
    j. Train to Wayside Communications equipment shall have an MDBCF of 170,000 miles.
7. The Contractor shall propose and utilize a Failure Reporting And Corrective Action System (FRACAS) that is a closed loop failure reporting system used to record all failures throughout the production and warranty phase of the Contract and the monthly reporting of MDBF.

2.9 MAINTAINABILITY

2.9.1 General

1. The vehicle design shall incorporate approaches which minimize Mean Time To Repair (MTTR) and maintenance costs throughout its intended useful life.
2. The Contractor shall develop a maintainability program for the vehicle, including corrective and preventive maintenance, which shall provide for enhancement of vehicle availability, and the minimization of maintenance costs.

2.9.2 Maintenance Plan

1. The Contractor's maintainability program shall include a detailed plan outlining all schedules and activities for vehicle preventive maintenance.
2. This plan, along with the outline of the proposed maintenance manuals and associated drawings, shall be submitted to the SFMTA for acceptance as according to the Project Delivery Schedule defined in Exhibit 3 of the Agreement.
3. The plan shall outline each maintenance task, time schedules, recommended tools, personnel, and skill levels required.

4. These recommendations shall be based upon those of the Contractor and of the equipment suppliers.
5. The weighted average of the component MTTR shall illustrate compliance with the overall MTTR requirements.
6. This plan shall be coordinated with the maintenance manuals and agree with them.

2.9.3 Maintenance

1. The LRV shall be designed for ease of routine and corrective maintenance, such as to minimize maintenance time, and hence life cycle cost.
2. The maintenance schedule shall be designed to minimize life cycle costs.

2.10 CODES AND REGULATIONS

1. All equipment shall comply with all applicable local, state and federal rules, codes, standards, and regulations. Contractor shall pay particular attention to the requirements of CPUC General Order 143B.

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3 CARBODY STRUCTURE

3.1 PERFORMANCE REQUIREMENTS

3.1.1 Corrosion Prevention

1. The materials used in the car body shall be protected from corrosion.
2. Dissimilar metal joints shall be protected against electrolytic corrosion.
3. The structure shall be designed to eliminate all water traps.

3.1.2 Static Loads

1. The car body shall be designed to meet the static load requirements of CPUC GO 143.
2. Jacking pads and supporting structure shall be designed to withstand without permanent deformation 200% of the normal jacking loads in the vertical direction combined with 110% of the normal jacking loads in the transverse direction.

3.1.3 Fatigue Loads

1. The car body shall be designed to resist the alternating loads that occur in normal service over the life of the car without fatigue failure. Designs shall be based on allowable stresses for 10 million cycles.
2. The fatigue loads are to be a combination of the following minimum load components, zero to peak:
   a. Longitudinal load component in the X direction of 15% of car body weight at AW2;
   b. Lateral load component in the Y direction of 15% of car body weight at AW2;
   c. Vertical Load component in the Z direction of 20% of car body weight at AW2;
   d. 15% of worst case torsion between adjacent trucks.
3. The loads listed above shall be applied in the phasing that results in highest stresses at critical locations.

3.1.4 Crash Energy Management

1. Design for crash energy management shall be in accordance with ASME RT-1 for LRV's to the extent this is compatible with the requirements of CPUC GO 143.

3.1.5 Allowable Stresses

3.1.5.1 Static Strength

1. The limiting static material properties shall be the minimum yield strengths as given in the material specifications in Section 19.
2. The values used shall be taken from ASME RT-1 for LRV's.

3.1.5.2 Fatigue Strength of Welded Structure

1. Structural welding practices shall be according to requirements of;
   a. AWS D1.1, "Structural Welding Code – Steel;"
   b. AWS D1.2, "Structural Welding Code – Aluminum;"
   c. AWS D1.3, "Structural Welding Code – Sheet Steel;"
   d. AWS D1.6, "Structural Welding Code – Stainless Steel;" and
   e. The AWS Handbook.
2. Requirements for dynamically loaded structures shall be applied.
3. Cast steel welding shall be according to ASTM A 488/488M, "Steel Castings, Welding, Qualification of Procedures and Personnel."
4. Resistance welding shall be in accordance with AWS D17.2/D17.2M, Class B for structural applications and Class C for non-structural applications.
5. Materials joining processes other than those listed here shall be for infinite life to a standard to be approved by the SFMTA.

3.1.6 Water Tightness and Drainage

1. The car body shall be designed to prevent the accumulation and ingress of water.
2. Roof drains shall be accessible for cleaning and protected from blockage by leaves or other foreign material.
3. Rain gutters shall be provided over doorways and cab side windows.
4. Splashboards shall be positioned at the end of the roof to minimize the cascading of water during acceleration and braking.

3.1.7 Bodyside Flatness

1. All car body exterior surfaces shall be free of ripples exceeding $^{3}/_{32}$-in (peak to valley) in 3 ft measured in any direction, before fillers are applied, and the use of such fillers shall be minimized.

3.1.8 Anticlimber

1. The anticlimber shall be wide enough to engage the anticlimber of an opposing vehicle (existing LRV2/3 or new LRV4 type) under the worst-case condition of vehicle-to-vehicle relative position on horizontal track curves.
2. A jack pad shall be provided under the center of each anticlimber.
3. A towing hitch shall be provided to allow recovery of other vehicle types, and to allow attachment of a safety strap used in dead tow situations per SFMTA standard operating procedures.

3.1.9 Exterior Finish

1. The LRVs shall have decals applied or be painted in approved SFMTA color scheme, with branding decals in number and location similar to the existing fleet.

3.2 VALIDATION REQUIREMENTS

1. Validation requirements shall be in accordance with ASME RT-1, to the extent these are compatible with the requirements of CPUC GO 143.
2. The fatigue analysis is to be used to demonstrate the ability of the carbody to survive its intended operational requirement without fatigue failure.

3.3 INTERFACE REQUIREMENTS

3.3.1 Jacking Pads and Lifting Points

1. The vehicle shall be provided with jacking pads and lifting points to facilitate routine maintenance operations, emergency lifting, and rerailing.
2. Jacking and lifting points shall be compatible with the SFMTA's current maintenance equipment.
3. Jacking pads shall be designed with an anti-slip surface.

3.4 MAINTENANCE REQUIREMENTS

1. The car body structure and finish shall be compatible with the SFMTA's existing car washing equipment and chemicals.
2. Roof access shall be compatible with SFMTA shops. The LRV roof shall be designed for maintenance accessibility and roof surfaces and equipment covers shall support maintenance personnel and their tools.

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4 COUPLER

4.1 PERFORMANCE REQUIREMENTS

4.1.1 Automatic Couplers

1. Each coupler shall provide fully automatic mechanical, electrical and, if applicable, pneumatic coupling between LRV4 vehicles.
2. Each coupler shall provide fully automatic mechanical, and, if applicable, pneumatic coupling (air supply only) to LRV2/3 vehicles. Electrical trainline compatibility is not required.
3. Couplers shall be self-centering.
4. The coupler shall have draft gear providing cushioning in buff and draft.
5. The coupler system shall permit operation of a maximum-length train under normal conditions.
6. Couplers shall have automatically operated covers which conceal and protect the electrical portion when not in use for trainline functions.
7. The coupler equipment and controls shall provide, at a minimum, the following functions:
    a. Automatic coupling;
    b. Operator-activated uncoupling;
    c. Operator-activated electrical isolation;
    d. Manual mechanical uncoupling; and
    e. Manual isolation and reconnection of the electric trainline functions.

4.2 PERFORMANCE REQUIREMENTS

4.2.1 Mechanical Coupler

4.2.1.1 Geometric Requirements

1. The coupler system shall be capable of operating over all track profiles, including worst-case horizontal and vertical curves singly and in combination, superelevation, track wear, and track misalignment without damage to the coupler, other equipment, or the vehicle structure.
2. In addition, the coupler system shall accommodate variations between adjacent cars resulting from uneven loading, wheel wear, maximum suspension travel, and suspension failure without damage to the coupler, other equipment, or the vehicle structure.

4.2.1.2 Gathering Range

1. The gathering range of the coupler and the centering and leveling device tolerances shall be sufficient for two vehicles with correctly adjusted couplers to automatically

couple on level tangent track under the worst-case combination of permitted wear and vehicle displacement.

2. The distance shall be as follows: Measured from the centered position, at least ±3 inches in the vertical direction and ±6 inches in the horizontal direction.

4.2.1.3 Strength Requirements

1. The coupler assembly shall be capable of withstanding buff or draft loads up to a minimum of 110 % of the maximum release load of the coupler.
2. The coupler shall be designed to:
    a. Have sufficient strength to withstand an upward vertical load for lifting the end of an AW0 vehicle, including the adjacent truck, from beneath the mechanical coupler, when proper blocking is provided between the coupler and the end sill.
    b. Withstand a downward vertical load of minimum 400 lbf applied at the coupler head at its maximum installed longitudinal outboard dimension, and for any possible lateral position, without causing any permanent damage to the coupler and its supporting car body structure.

4.2.1.4 Energy Management

1. As a minimum, the design shall provide for one AW0 vehicle moving into another AW0 vehicle parked with the brakes applied, under the following conditions:
    a. The draft gear and/or energy absorbing elements shall manage coupling for all speeds up to 5 mph and self-restore, with no permanent deformation to any of the coupler elements or to the vehicle.
    b. For all coupling/collisions above 5 mph the draft gear elements and/or energy absorption unit(s) shall compress, followed by activation of the release mechanism to allow the coupler system to retract a sufficient distance to permit the car body anticlimbers to engage.
    c. If the collision forces are sufficiently high such that compression continues following the full retraction of the coupler system, the coupler system shall not impede the Crash Energy Management (CEM) response of the car body to overload conditions.
    d. The coupler system shall be supported in a safe manner at all times. The coupler shall not drop to the track.
    e. Partial release shall be clearly detectable by maintenance staff and correctable in the maintenance shop without coupler removal.

4.2.2 Pneumatic Coupling (if applicable)

1. Manual isolation of the pneumatic trainlines shall be possible with the use of a cut-out cock located inboard of the hoses, so that the hoses are isolated.

4.2.3 Electric Coupler

1. Each electric coupler shall be provided with a weather-resistant front cover to protect the contact area from the environment when closed.

4.3 INTERFACE REQUIREMENTS

1. For pushing and towing purposes, LRV4 cars shall be able to couple mechanically with existing LRV2/3 cars, and, if the LRV4 uses an air system, pneumatic coupling shall be possible, otherwise the coupler shall not cause loss of air from an LRV2/3. Electrical coupling is not required.
2. The LRV2/3 uses a Dellner Coupler Type 100 coupler. If the electric coupler trainline configuration will be different than the existing LRV, the Contractor shall ensure that the electric coupler heads of both vehicles will not extend and make contact during mechanical coupling.
3. LRV4 cars shall be provided with a hitch to allow attachment of a safety strap for use in dead tow situations.

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5 OPERATOR'S CAB

5.1 GENERAL

5.1.1 Introduction

1. The general arrangement of the cab shall be full width, with the Operator located on or close to the LRV centerline.
2. The cab partition shall be full width, with a closed and locked access door when not in use, with a window that can be opened to provide access to the farebox when in use.

5.2 PERFORMANCE REQUIREMENTS

5.2.1 Arrangement

1. The general arrangement of the cab controls and indications shall enable all normal driving functions to be performed while the operator is seated and subject to the required Ergonomic and Human Machine Interface analysis using the 2.5 percentile Female and the 97.5 percentile Male.

5.2.2 Visibility Requirements

5.2.2.1 Forward Visibility

1. An operator, in all possible operator seat adjustment positions, shall be provided with:
   a. A minimum vertical upward view sufficient to view signals;
   b. A downward view sufficient to see a 39-inch tall person standing 19.5 inches from the front-most surface of the vehicle;
   c. A minimum 90 degrees about the horizontal line of sight in the forward direction (i.e. 45 degrees to each side);
   d. Minimum "blind spots" such as might be caused by A-pillars or other obstacles that may block sections of viewable area from the operator; and
   e. Distortion-free windshield in the required field of view.

5.2.2.2 Rearward Visibility

1. The operator shall be provided with a means of viewing the passenger compartment.

5.2.2.3 Sideward Visibility

1. The operator shall be capable of viewing automobile traffic lanes at mixed-traffic intersections in order to safely execute left and right-hand turns.

5.2.2.4 Platform Visibility

1. From a seated position, the operator shall be capable of viewing passenger egress consistent with Section 13.3.3, item 2, and compliant with CPUC GO143B and recorded as required in Section 13.3.3, item 3.

5.3 SPECIFIC REQUIREMENTS

5.3.1 Operator's Seat

1. The operator's seat shall have ability to adjust: the height, fore/aft travel, and lumbar support and shall accommodate the human engineering factors as specified in Section 1.5.

5.3.2 Diagnostics Display

5.3.2.1 General Requirements

1. The diagnostics display shall be of a 2-tier design; operator mode and maintenance mode.
    a. Operator mode:
        i. The Operator mode shall be the default display.
    b. Maintenance mode:
        i. The Maintenance mode shall be activated by a key switch or inputting a PIN password (alternatives to a PIN may be proposed).
        ii. The Maintenance mode shall provide access to more in depth diagnostics that a maintainer would require.

5.3.2.2 Operator Mode

5.3.2.2.1 Default Operator Screen

1. In operator mode, the diagnostics display shall display:
    a. Train configuration.
    b. Operating status of all critical systems.
    c. Vehicle parameters of all major subsystems.
    d. Fault display with instructions to the operator whenever a critical fault that requires operator intervention is detected.

5.3.2.3 Maintenance Mode

1. In maintenance mode the diagnostics display shall provide an interactive interface to review diagnostic data.

5.3.3 Master Controller

5.3.3.1 General

1. A master controller group consisting of reverser switch, and hand operated master controller and shall be supplied as a single integrated unit.
2. The master controller shall operate in the car longitudinal direction, with power forward and brake to the rear, with the rearmost position being Emergency Brake.
3. Trainlined control signals shall comply with the requirements of IEEE STD 1475.

5.3.3.2 Interlock

1. The master controller shall be mechanically interlocked so that the master controller is inactive when the cab control switch is in the “OFF” position.
2. The master controller shall be operative only when the direction control selector is moved to the “FORWARD” or “REVERSE” position.
3. A change of mode from “FORWARD” or “REVERSE” to “OFF” or vice-versa shall be impossible unless the master controller is at neutral, and vehicle is at zero-speed and parking brake is applied.

5.3.3.3 Master Controller Function

1. A single master controller handle shall be provided to issue the command signals to the propulsion and braking systems.
2. The master controller shall operate in a proportional manner in both power and brake from the respective minimum to maximum positions.

5.3.4 Deadman Feature

5.3.4.1 General

1. An operator’s Deadman feature shall be incorporated in the vehicle controls to safely stop the vehicle in the event of the incapacity of the operator.
2. The Contractor shall provide at least two independent methods of Deadman activation to decrease operator fatigue.

5.3.5 Emergency Stop Pushbutton

1. An emergency stop pushbutton shall be provided at location on the operator’s console approved by SFMTA.

5.3.6 Windshield Wipers

1. The windshield wiper shall wipe sufficient width and height to provide required visibility for driving purposes.
2. The windshield wiper shall have at least two frequencies or speeds.
3. The design shall have an arrangement that automatically returns the wiper to a “PARK” position when the control is switched off.

5.3.7 Windshield Washer

1. A windshield washer system shall be installed to enable the operator to eject onto the windshield a cleaning and/or anti-freezing agent of the standard automotive type.

5.3.8 Sun Screen

1. A sun screen or shade shall be provided for windshield and side windows.

5.3.9 Fire Extinguisher

1. A class 4-A-60BC fire extinguisher shall be located in each operators cab.

2. The fire extinguisher shall be 10lb capacity.

5.3.10 Miscellaneous

5.3.10.1 Coat hook

1. A coat hook shall be provided in each cab.

5.3.10.2 Cabinets

1. A cabinet suitable for the storage of emergency equipment shall be provided within the cab.
2. A second cabinet/space for the operator’s belongings shall be provided within the cab.

5.3.10.3 Covert Alarm

1. A covert alarm that allows the operator to push a button and alert central control via the radio system of an emergency, shall be provided.

5.3.11 Rear Wall and Cab/Saloon Partition Door

1. The door between the cab and the passenger area shall be in a locked position from the passenger side when the door is in the closed position.
2. An window, which shall be locked when closed, shall be provided to allow passenger access to the farebox.
3. The door shall be equipped to allow the operator to exit the cab quickly in an emergency.
4. Rearward visibility of the passenger compartment by the operator shall be provided, with neutral tinted glass provided above waist level in the partition.

5.3.12 Run Number Sign

1. An illuminated run number sign shall be provided and installed to the right of the Operator's position in each cab.

5.3.13 SFMTA Defined Equipment

1. The cab shall accommodate train control, communications and fare systems equipment to be defined by SFMTA. A listing of SFMTA defined equipment is provided in Section 23.
2. SFMTA defined equipment shall be supplied, installed, integrated, and tested by Contractor, unless otherwise specified.

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6 PASSENGER DOORS

6.1 GENERAL

1. The door system shall comply with the following standards:
   a. APTA SS-C&S-012-02, Standard for Door Systems for New and Rebuilt Passenger Cars.
   b. 49 CFR 38, Americans with Disabilities Act (ADA) Accessibility Specifications for Transportation Vehicles, Subparts A and D.
   c. 49 CFR 238, Passenger Equipment Safety Standards, Section 238.235.
2. When enabled by the operator (at low level platforms), passengers shall be able to command door opening from internal and external controls.
3. To accommodate both platform and street-level boarding, moveable steps shall be provided at all door locations. The changeover shall be controlled from the active cab. The changeover shall also automatically change the warning device from gong when the steps are down, to horn when the steps are up, and shall be equipped with an override feature.
4. All major door components (mechanisms and controls) shall be interchangeable between doorways.

6.2 PERFORMANCE REQUIREMENTS

1. The maximum force exerted on an obstacle during the closing motion of the door shall not exceed the following:
   a. The force of an impact on a person or obstacle shall be limited to a maximum of 65 lbf.
   b. The effective mean force including further closing attempts after obstruction detection shall be limited to a maximum of 45 lbf.
   c. These values shall be measured in accordance with the method described in EN 14752 Appendix D.
2. The trainline signals shall be interlocked with the no-motion circuitry, such that door trainline commands cannot be activated unless the train is stopped.

6.3 SPECIFIC REQUIREMENTS

6.3.1 Door Panels

6.3.1.1 Strength Requirements

1. The door panel system shall have the strength and rigidity to sustain passenger loading due to overcrowding conditions without activating sensors or causing permanent deformation.

6.3.2 Door Operator

6.3.2.1 Manual Emergency Release

1. An interior and exterior emergency manual release mechanism shall be provided at each side doorway.
2. The emergency manual release shall comply with the requirements of 49 CFR 238.235.

6.3.3 Obstruction Detection

6.3.3.1 Operational Requirements

1. Upon sensing an obstruction, the local door controls shall cause the door operator(s) on the obstructed panels to immediately reverse and open.
2. The controls shall attempt to reclose the panels three times before remaining open.

6.3.3.2 Sensitivity Requirements

1. Obstruction detection sensitivity shall be as specified in APTA SS-C&S-012-02, Section 5.3.4.1.

6.3.4 Control Switches and Pushbuttons

6.3.4.1 General Requirements

1. The doors shall be controlled from the crew switches, the Operator's cab door control pushbuttons, and the passenger pushbuttons.

6.3.4.2 Crew Switches

1. A crew switch operated by the standard crew key shall be located outside and inside, as a minimum, at one door per side per vehicle (closest passenger access door to the cab), each diagonally opposite the other.

6.3.4.3 Operator's Console Door Control Pushbuttons

1. The door control panel shall include the following functions:

   (a) Open/close right front door of the vehicle

   (b) Open all right side doors

   (c) Release all right side doors and enable passenger door controls

   (d) Close/lock all right side doors

   (e) Open/close left front door of the vehicle

   (f) Open all left side doors

   (g) Release all left side doors and enable passenger door controls

   (h) Close/lock all left side doors.

6.3.4.4 Passenger Controls.

1. Each side door opening shall be provided with controls on both sides of the doorway on both the inside and outside of the vehicle, for use by passengers.

2. Internal control shall be using touchbars, similar to the existing LRV2/3 fleet.
3. External pushbuttons shall be located to be accessible from low level platforms – access at high level platforms is not required.
4. Door panels opened from the passenger pushbuttons shall automatically close after a time delay, which shall be adjustable from 2 to 30 seconds.

6.3.5 Bypass Devices

6.3.5.1 General Requirements

1. Bypass devices shall be provided to circumvent specific door system faults so that the train can continue in revenue service, or be removed from revenue service. In these situations the bypassed door shall be physically locked closed.

6.3.6 Annunciations

6.3.6.1 Door Out-of-Service Illuminated Sign

1. An illuminated sign stating "DOOR OUT-OF-SERVICE" sign shall be provided on the vehicle interior at each doorway. The sign shall be illuminated any time a door is removed from service by activation of the DOOR OUT-OF SERVICE switch.

6.3.6.2 Door Closing Warning Signals

1. Audible and visual warnings shall be initiated at each doorway to warn the passengers that the door has been commanded to open or close in accordance with 49 CFR Part 38.

6.3.7 Step System

1. The step modes and the changeover cycle shall not interfere with the operation and physical position of the doors.
2. When changing from low to high, or vice versa, the top surface of the steps shall remain horizontal at all times.
3. In the high-level position, the threshold and loading area shall be a single surface set flush with the normal interior floor level.
4. The steps shall be capable of operating in either direction with a uniformly distributed static load of 500 pounds, and of remaining in either position for extended periods of time whether or not power is available to the car.
5. Step operation shall be interlocked with the door operation to ensure that, at high level platforms, doors cannot open until the associated step is in the selected position.
6. An audible warning shall sound at the step location whenever the high/low switch is activated and steps are in the process of changing position.
7. There shall be an interlock for the step system such that left side doors cannot be unlocked or opened when the right side steps are down, except for the forward most left side door.
8. The left side steps shall be raised up whenever a cab is keyed-on.
9. All the steps shall be set to same level as the lead car whenever the cars are coupled.

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7 HEATING, VENTILATION, AND AIR COOLING

7.1 PERFORMANCE REQUIREMENTS

1. The control system shall be designed to automatically maintain the car interior temperature, including both cabs, at the conditions specified in Section 2.3.3.2, with variable internal heat loads such as passengers, motors, lights and solar gain, when the auxiliary power supply (APS) is at its nominal voltage.

7.2 SPECIFIC REQUIREMENTS

7.2.1 Heating System

7.2.1.1 Heater Guards

1. The temperature of surfaces accessible to passengers and operators shall not exceed 125°F.

7.2.1.2 Windshield and Cab Side Windows heaters

1. The heater/window defroster system shall have the appropriate capacity to provide for defrosting the glass in 10 minutes under the worst-case temperature and humidity parameters specified in Section 2.

7.2.2 Ventilation

7.2.2.1 General

1. A ventilation fresh airflow of not less than 5 ft^3/min per AW2 passenger shall be provided at all times when the vehicle is in passenger service.
2. Full ventilation shall be continuously available when the vehicle is in passenger service even in the event of failure of the refrigeration system.

7.2.2.2 Air Filters

1. The filters and filter holders shall be designed in a commercially available standard size and available for sale from at least two US commercial-industrial HVAC distributors.

7.2.3 Cooling System

7.2.3.1 Refrigerant

1. The air-cooling unit shall be designed for and delivered with a refrigerant approved by the United States Environmental Protection Agency (USEPA).

7.2.3.2 Design Criteria

1. The air cooling equipment shall have sufficient capacity to condition the air inside the car to the requirements and loads defined in Section 2.3.3.2.

2. The cooling system shall be able to start and operate without damage at any time of the year when the exterior temperature is above 50 degrees Fahrenheit, and when interior car conditions require cooling to meet the specified interior temperatures.

7.2.4 Controls

7.2.4.1 Interior Car Conditions

1. When the ambient temperatures are outside the design limits presented in Section 2.3.3.1, the interior temperatures shall be as follows:

Table 7-1 Interior Car Conditions

Ambient Temperature; (T_a)	**Interior Temperature; (T_i)**
Less than Minimum Ambient	T_a + 43°F
Maximum Ambient to Maximum Ambient +15°F	T_a - 20°F
Greater than Maximum Ambient + 15°F	As the system will provide.

7.3 VALIDATION REQUIREMENTS

7.3.1 Qualification and Climate Room Testing

Tests shall be conducted to validate HVAC system performance in accordance with the requirements of this specification.

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8 LIGHTING

8.1 GENERAL

1. All lighting on the vehicle shall utilize high efficiency, i.e. Energy Star, components to reduce power consumption.
2. LED technology shall be used where practical for illumination.

8.2 PERFORMANCE

1. The headlights shall be arranged to illuminate a person at least 800 feet ahead and in front of the vehicle.
2. Passenger compartment and Operator cab lighting shall conform to EN 13272 for mass transit vehicles except as detailed in this Technical Specification.
3. The exterior lighting shall conform with CPUC GO143B requirements.

8.3 SPECIFIC REQUIREMENTS

8.3.1 Emergency lighting

1. Emergency lighting shall be in compliance with APTA RT-S-VIM-020-08.
2. The following lights shall remain functional under emergency power conditions for a minimum of one hour:
    a. Lights near the doors and doorway lights for illuminating platforms.
    b. Main interior lights such that total emergency lighting meets the above standards for luminance vs. time.
    c. Operator cab and control panel lights.
    d. Direction indicator lights (4 way flashers) in the emergency flashing mode.
    e. Side and End Marker Lights.
    f. Headlights.
    g. Tail lights.
    h. Stop lights.

8.3.2 Exterior Lighting

8.3.2.1 General:

1. The exterior lighting shall include headlights, stoplights, taillights, marker lights, directional indicators with four-way flasher function, door open warning lights, door out of service indicators and doorway lights.

8.3.2.2 Marker Lights

1. Two green marker lights shall be located at each end of the vehicle on the sides of, or above, the A-end destination sign.

2. Two red, upper marker lights shall be located at each end of the vehicle on the sides of, or above, the destination sign.
3. Two red, lower lights "tail lights" shall be located one in each of the clusters at each end of the vehicle.

8.3.2.3 Brake Lights

1. Brake lights on the vehicle shall illuminate automatically under any one of the following conditions:
    a. On a brake command;
    b. On an emergency stop command;
    c. The vehicle is stopped or parked.

8.3.2.4 Local Car Fault Lights

1. One blue LED lamp, visible in both directions, shall be installed on both sides of the vehicle to indicate the presence of one of the following local car faults:
    a. Propulsion System,
    b. Auxiliary Inverter,
    c. Friction Brake System,
    d. Bypass/cut-out in use.

8.4 MAINTENANCE REQUIREMENTS

1. All consumable lamps and ballasts shall be of a standard type commercially available from two proven sources in North America.

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9 ELECTRICAL

9.1 GENERAL

1. All electric devices, wiring and connections shall be selected to function properly and safely under the worst-case combination of the following:
   a. Ambient conditions,
   b. Equipment operating tolerances,
   c. Train length,
   d. Voltage drop in wiring connections including the coupler.
2. According to IEEE STD 16-2004:
   a. The vehicle electrical circuits shall be physically and functionally segregated;
   b. The Contractor must define selected parameters;
   c. All equipment on the vehicle, including resiliently mounted equipment, truck frame, and truck-mounted equipment, shall be safety grounded and bonded to the vehicle structure;
   d. The vehicle structure shall be safety grounded to the axles and to the tires, if independently rotating or resilient wheels are used.
3. Gap and creepage distances shall comply, as a minimum, with the recommendations of APTA RP-004-98.

9.2 SPECIFIC REQUIREMENTS

9.2.1 Circuit Protection

9.2.1.1 General Circuit Protection

1. Auxiliary apparatus and their controls shall be designed such that all devices are able to withstand the transients as specified in IEEE STD 16-2004 Section 4.3.

9.2.2 Connection

9.2.2.1 General

1. Each connector shall contain 10% spares or a minimum of one spare by approval of SFMTA.

9.2.2.2 Wiring

1. Wiring shall conform, at a minimum, to the requirements of APTA RP-E009-98.
2. Vehicle wiring shall comply with NFPA 130, section 4-3.7. Wiring within enclosures shall comply with IEEE Std.16-2004, section 4.8.

9.2.3 Primary Power System

9.2.3.1 Shop Power Connection

1. Shop power connection shall be on the side of the car, positioned at a similar location as the existing LRV2. The plug shall mate with Pyle National part #3024, 600 volt, 200 ampere, 5-pin shop connectors.

9.2.3.2 Pantograph

1. The pantograph design shall comply with IEC 60494-2 requirements.
2. The minimum static pantograph uplift pressure shall be sufficient to maintain contact under all normal conditions without causing excess wear.
3. An automatic drop feature shall be provided to lower the pantograph to reduce damage to the pantograph itself and the overhead wire during and after contacting an obstruction whenever some part of the pantograph contacts an obstruction equaling 300 lbf or greater.
4. A shear pin safety system shall be provided to minimize pantograph and contact line damage caused by hard contact between some part of the pantograph and an overhead obstruction.
5. Impact shall cause the pin to shear, causing the pantograph to drop to its lowered position.
6. Provision shall be made for manually raising, lowering and unlatching the pantograph in the event of a loss of power or control.

9.2.4 Convenience Outlets

1. A minimum of two (2) duplex convenience outlets shall be installed for 120 VAC, 20 A service within the carbody.
2. One (1) duplex outlet shall be provided in each cab.

9.2.5 Battery

1. The battery shall be sized to provide at least the following loads, with associated duty cycles:
    a. Door Control (cycle doors open for 20 s every two (2) minutes),
    b. Communications (operate PA and radio 20 s every two (2) minutes),
    c. Propulsion and Braking Control (continuous),
    d. ATP, Cab Signal or Train Stop Equipment (continuous),
    e. Operator’s Console Indicators, and Interlocks (continuous),
    f. Gong and Horn (on for five (5) s every two (2) minutes),
    g. Track Brakes (on for 30 s at end of each 20 minute period),
    h. Pantograph Control (raise and lower twice),
    i. Coupler control (one (1) couple and uncouple cycle),
    j. Windshield Wiper (continuous),
    k. Train-to-Wayside Communications (continuous),

l. Event recorder (continuous),
m. MDS,
n. CCTV,
o. Brake system hydraulic pump motors (if applicable),
p. Propulsion container blower fans (if LV DC powered),
q. Emergency Lighting per Section 8.3.1.

2. For an initial battery condition with the cells at 80% of full charge and the ambient temperature appropriate for the range specified in Section 2, the battery capacity shall be able to carry all the above loads for a period of one hour.

9.2.6 Controls

9.2.6.1 Primary Power Switch

1. The switch shall provide the following positions and functions, with positions labeled as indicated:
    a. RUN- In this position, main power from the current collector shall be connected to both propulsion and auxiliary circuits. The switch shall be in this position in normal operation.
    b. OFF- In this position, both the propulsion and auxiliary circuits shall be completely isolated from main power.
    c. AUX- In this position, propulsion circuits shall be completely isolated from main power, and main power from the current collector shall be connected only to the auxiliary circuits.
    d. SHOP- In this position, propulsion circuits shall be completely isolated from main power, and main power from a shop power connector shall be provided only to the auxiliary circuits provided that the shop power connector is connected to a wayside source.

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10 PROPULSION

10.1 PERFORMANCE

10.1.1 General

1. Propulsion and braking equipment shall comply with the applicable sections of IEEE STD 16-2004.
2. The operating environment must be considered in the design of the propulsion equipment to prevent the entry of moisture, dust, sand, dirt, and debris. The Contractor shall propose equipment enclosures that will keep the equipment cool, clean, and reduce maintainability.

10.1.2 Duty Cycle and Thermal Performance

10.1.2.1 General

1. The propulsion system ratings shall be based on the worst-case duty cycle defined in this section.

10.1.2.2 Normal Duty

1. The propulsion system thermal capacity shall exceed by at least 10% that required to operate continuously without damage over the LRT system under the following conditions:
    a. Route profile and schedule as specified in Section 2.
    b. AW2 loading.
    c. All propulsion systems operative.
    d. Line voltage within the limits specified for full performance in Section 2.
    e. Maximum ambient temperature as specified in Section 2.

10.1.2.3 Abnormal Operating Modes

1. The propulsion system thermal capacity shall be at least that required to make one round trip without damage over the LRT system under the following conditions:
    a. Route profile and schedule as specified in Section 2.
    b. AW3 loading.
    c. Half of all propulsion systems operative; half inoperative.
    d. Line voltage at the minimum limit specified for full performance in Section 2.
    e. Rheostatic electric braking only.
    f. Fully operative friction braking on all vehicles.
    g. Maximum ambient temperature as specified in Section 2.

10.1.2.4 Towing

1. Unless otherwise approved by the SFMTA, it shall be possible for a train with normally operating vehicles to tow an equal number of vehicles with inoperative

propulsion systems from any point on the LRT system to the appropriate maintenance facility without damage to any of the vehicles, under the following conditions:

a. Train speed limited to not less than 20 mph.

b. AW3 loading to the next station, at which point all passengers are discharged; AW0 loading thereafter.

c. Line voltage at the minimum limit specified for full performance in Section 2.

d. Fully operative friction braking on the vehicles being towed.

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11 TRUCK REQUIREMENTS

11.1 GENERAL

1. Trucks of a like design shall be interchangeable.
2. Trucks shall be compatible with SFMTA shops, including cranes, turntables, presses, in-floor jacks, wheel truing lathes.

11.2 PERFORMANCE REQUIREMENTS

11.2.1 Truck Connection to Carbody

1. Strength of connection shall be in accordance with ASME RT-1.

11.2.2 Wheel Load Equalization

1. Equalization shall be such that with the car on level track under an AW0 load, lifting or dropping any wheel 1.50 in shall not change the load on any other wheel of the car by more than 60%.
2. Raising or lowering any wheel up to 2 in shall not result in loss of contact between any of the other wheels on the car and the rail.

11.3 SPECIFIC REQUIREMENTS

11.3.1 Design Loads

1. The basis for determining maximum load variation for static and fatigue loadings shall include forces resulting from passenger load, track shocks and forces, motor torque, friction brakes, track brakes, and any possible combination of these forces when operating under all possible conditions on track not condemnable under SFMTA's maintenance standards, at speeds up to and including 110% of maximum revenue service speed.
2. Under these conditions, stresses shall not exceed allowable fatigue stresses 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 used.
3. Allowable fatigue stresses for truck materials shall be limited to published endurance stress values.
4. Allowable fatigue stresses for welded connections shall not exceed the requirements of AWS D1.1 for Dynamic Structures or Contractor tests of the specific connection establishing its endurance stress (load) value for 95% survival at 69% confidence level.

11.3.2 Truck Features and Component Design Requirements

11.3.2.1 Wheels, Axles and Bearings

11.3.2.1.1 Wheels

1. The shunting resistance of each assembled wheel set shall not exceed 0.01 ohms when measured across the axle from tire tread to tire tread.

11.3.2.1.2 Axles

11.3.2.1.2.1 General Requirements

1. Both ends of each axle shall be chamfered and furnished with standard 60° at the centers for tram measurements and wheel truing.
2. The axle assembly components shall be designed to be compatible with SFMTA's wheel press and wheel truing machine.

11.3.2.1.3 Bearings

1. Journal bearings shall be designed for a minimum L-10 life rating of 1,000,000 miles based on an AW3 vehicle weight with loads typical of light rail operation.
2. The bearings shall be fully enclosed, shall not require field lubrication, and shall not require inspection more than once every 150,000 miles.

11.3.2.2 Obstacle Deflectors

1. Each end truck shall be provided with safety bars at its outer or lead end, to deflect debris and to prevent such material from getting under the truck per CPUC GO143B requirements.

11.3.2.3 Sanding Equipment

1. Sanding nozzles shall be positioned so as to deposit sand immediately in front of the leading wheels on all powered trucks as per Section 12.2.3.

12 BRAKING EQUIPMENT **12-1**

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12 BRAKING EQUIPMENT

12.1 PERFORMANCE REQUIREMENTS

12.1.1 Design Criteria and Requirements

1. Without the aid of dynamic braking the friction brake system shall be capable of one (1) emergency brake application from maximum rated speed followed by continuous friction only revenue service from the furthest point on the system to the maintenance facility, without damage.
2. The friction brakes shall be mounted so that they are protected to the greatest extent possible against damage due to minor collisions, automobile side impacts, derailments, dirt, dust, ballast and water.
3. A sanding system shall be provided that deposits friction enhancing material in the front of leading wheels.

12.2 SPECIFIC REQUIREMENTS

12.2.1 Friction Braking

1. A means for emergency release of the disc brake system, over and above an electrically commanded override from the operator’s cab, shall be incorporated.
    a. The emergency release must be accessible to the crew under all conditions.
    b. Manually released calipers shall be reset to normal operation on the next normal service application.

12.2.2 Hydraulics (if used)

1. The hydraulic fluid shall be commercially available in the North American market.
2. Use of a hand pump as the only means to manually release the brakes will not be permitted. Use of a dc drive motor may be considered for this purpose, however an ac motor will not be acceptable.

12.2.3 Sanding System

1. The sand box shall be filled from outside the car.
2. Sanding shall be applied automatically to assist in spin/slide control and to achieve the required acceleration and deceleration rates without excess usage.
3. The automatic use of sand shall be optimized to minimize sand consumption.
4. Manual application shall be possible and operational regardless of vehicle speed.

12.3 MAINTENANCE REQUIREMENTS

1. The Contractor shall identify any specialized maintenance facility requirements that are necessary for the servicing of the hydraulic system components (i.e. clean room), if used.

2. Equipment necessary to filter and/or decontaminate the hydraulic system (if used) shall be supplied (3 complete sets).
3. Should an air compressor be used, DC motors are not acceptable.

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13.3.1 Audio Systems 13-1

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13.3.3 Vehicle Interior/Exterior Surveillance and Rear View System 13-2

13.3.4 Automatic Passenger Counting System 13-2

13.3.5 Car to Car Data Communications 13-2

13 COMMUNICATIONS

13.1 GENERAL

1. Each car shall have a digital vehicle communication system (DVCS) installed to provide at a minimum the following:
   - Audio System
   - Radio System
   - Video System
   - Passenger Information Sign System
   - Wireless Data link
   - Local Ethernet Network
   - Infotainment System
   - GPS
   - Run Number Signs
   - Dynamic Route Signs
   - Automatic Passenger Counting System
2. Car-to-Car data communication system is defined in TS 23. It is the Contractor's responsibility to ensure that the installed system is compatible with the latest communication system on SFMTA LRV fleet.

13.2 PERFORMANCE REQUIREMENTS

13.2.1 Sound Level

1. The public address system's output level shall be automatically set in accordance with the ambient noise level in each individual car prior to activation of the amplifier for announcement.
2. The output level shall be a minimum of 15 dB above the interior ambient noise level resulting from vehicle operation at full speed.

13.3 SPECIFIC REQUIREMENTS

13.3.1 Audio Systems

13.3.1.1 General

1. The Audio System shall provide the following functionality:
   a. One-way communication from the Train operator to passengers (PA System).
   b. Two-way communication between the Train operator and the SFMTA's Train Control Center and/or SFMTA's Rail Supervisors (Radio).
   c. Two-way Passenger Emergency Intercom (PEI).
   d. Cab-to-cab intercom (Cab-to-Cab).
   e. Automatic announcements including route, destination, next station, time of day, etc. (PA System and Passenger Information Signs).

f. Interface with the vehicle interior and exterior message signs.
g. Passenger Emergency, Cab-to –Cab, PA Activation, PA Speaker Control, and PA Exterior Speaker Selection.
h. Configured such that failure of a CCU in a train does not cause loss of communications functions within the train.

13.3.1.2 Public Address System

1. The Contractor shall provide SFMTA with all necessary hardware, software, recording devices and all necessary tools to provide the SFMTA with the ability to record and up-load new announcements without the need for Contractor support.

13.3.2 Information Signs

1. The sign system for each car shall consist of two front-end destination signs, one run number sign per cab, four double-sided (interior and exterior view) side destination signs and at least two interior message displays.
2. Information conveyed shall include destination, location on route and next stop, as a minimum. Flexible signs capable of providing service information and alerts shall be provided.
3. All the information signs need to be controlled by radio vehicle logic unit using the latest SFMTA protocol.

13.3.3 Vehicle Interior/Exterior Surveillance and Rear View System

1. The surveillance system shall record not less than the most recent eight full calendar days of vehicle activity in all areas of the interior and exterior areas and be in full compliance with CPUC General Order 172.
2. At a minimum cameras shall cover all aisle, entry doors, seating areas, the interior of the cab with a full view of the Operator, and the Operator's view from the cab. The current planned configuration and the number of cameras and location are provided in Appendix A.
3. In lieu of side mirrors, the Contractor shall supply CCTV Cameras that will provide the operator with a clear view of the exterior of the train on both sides of the vehicle along the full length of the platform (high platform and street level) with two flat panel screens located near the corner posts on the left and right hand side of the cab for operator viewing. These cameras shall also meet the minimum recording requirements identified in Section 13.3.3, item 1 above.

13.3.4 Automatic Passenger Counting System

1. An Automatic Passenger Counting system shall be installed to record boardings and alightings at station stops. The means of reporting the data and the level of accuracy shall be compatible with SFMTA's existing systems.

13.3.5 Car to Car Data Communications

1. A Car-to-Car data communication system shall be furnished and installed for all onboard systems to communication between cars when the cars are coupled.

13.4 INTERFACE WITH RADIO, CAD/AVL SYSTEM

The following interfaces shall be furnished between the radio, CAD/AVL system and other vehicle systems. All the software shall be installed to SFMTA latest version at the time of delivery:

1. Farebox - The radio vehicle logic unit and farebox shall exchange the information through SAE J1587 messaging protocol over the SAE J1708 physical connection.
2. Destination Sign - Destination sign shall be controlled by radio vehicle logic unit through the Car-to-Car Data Communication network using existing protocol.
3. EA switch (each cab) shall be interfaced with radio vehicle logic unit.
4. GPS signal shall be interfaced with Surveillance Camera.
5. Critical Control Point Speakers (CCP Speakers), Destination signs, stop request, doors status shall interface with radio vehicle logic unit through cable connection.
6. Speed Sensors - Speed sensors shall be connected to radio vehicle logic unit.
7. Mobile Access Router - Router shall be connected to radio vehicle logic unit via 4 port Ethernet switch and to the Surveillance camera system.
8. Door Status - Front Right and left doors status shall be connected to radio vehicle logic unit.
9. Stop Request - Stop request shall be connected to radio vehicle logic unit.

13.5 LIST OF SFMTA DEFINED EQUIPMENT

1. The Contractor shall supply, install and test SFMTA specified equipment for the communication system. A listing of SFMTA defined equipment is provided in Section 23. It is the Contractor’s responsibility to ensure that the installed system is compatible with the latest communication system on SFMTA LRV fleet.

14 AUTOMATIC TRAIN CONTROL 14-1

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14.1.3 Automatic Train Control Interfaces 14-1

14.1.4 Train to Wayside Communications 14-1

14 AUTOMATIC TRAIN CONTROL

14.1 SPECIFIC REQUIREMENTS

14.1.1 Event Recorder

1. The event recorder shall comply with the requirements of IEEE STD 1482.1.
2. The event recorder shall be able to store a minimum of thirty (30) calendar days of most recent train operation data, including any signals from the spare channels, in non-volatile memory.

14.1.2 Alerter

1. The Contractor shall provide an Alerter subsystem (also known as an Alertness or Vigilance Control subsystem) in each basic operating unit.
2. The Alerter system shall interface with the Deadman control described in Section 5.

14.1.3 Automatic Train Control Interfaces

1. The Contractor shall supply, install and test an Automatic Train Control (ATC) system compatible with the SFMTA system. The current SFMTA system is defined in Section 13. All required interfaces with existing system shall be provided, including interface with Guaranteed Emergency Brake Rate (GEBR) system. The current setting for GEBR is 2.5mphs. The Contractor shall test for build up time and stopping distances for GEBR.

14.1.4 Train to Wayside Communications

1. Each basic operating unit shall be equipped with a Train to Wayside Communication system (TWC) to provide control of selected interlocking routes from on board the train.

14.2 LIST OF SFMTA DEFINED EQUIPMENT

1. The Contractor shall supply, install, and test SFMTA specified equipment for the ATCS and Train to Wayside communications systems. A list of equipment is provided in Section 23. It is the Contractor's responsibility to ensure that the installed system is compatible with the latest ATCS and Train to Wayside communications system on SFMTA LRV fleet

15 INTERIOR 15-1

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15 INTERIOR

15.1 SPECIFIC REQUIREMENTS

15.1.1 Emergency Egress and Access Provisions

1. Emergency egress and access shall be provided in accordance with standard APTA-RP-S-VIM-023-08.

15.1.2 Emergency Signage

1. Emergency signage on the vehicle interior and exterior shall be provided in accordance with standard APTA-RT-S-021-08.
2. Emergency exit path markings shall be provided in accordance with standard APTA-RT-S-022-08.

15.1.3 Glazing

15.1.3.1 Side and Door Windows

1. All side facing glazing shall meet the requirements of ANSI Z26.1.

15.1.3.2 Windshields

1. The windshield shall be constructed to meet the FRA Type I impact and ballistics requirements per 49 CFR 223.

15.1.3.3 Cab Side Window

1. The cab side windows to the left of the operator shall be capable of being opened.
2. The cab side windows shall be laminated safety glass constructed to meet the FRA Type II impact and ballistics requirements per 49 CFR 223.

15.1.4 Seating

15.1.4.1 Seat Construction

1. The seat construction and its attachments to the car body shall withstand, without permanent deformation, the loads to be reasonably expected in transit operation, including vandalism. Passenger seating may use inserts, however no fabric or cushions will be considered.

15.1.5 Stanchions and Handrails

1. Stanchions and handrails and their mountings and supports shall withstand the loads to be expected in transit service.

15.1.6 Advertisement Card Holders

1. Continuous card holder channels shall be located inside the car on the panels above the windows.

15.1.7 Keys and Locks

1. Two types of keys shall be supplied to provide access to all locks on the vehicle, as listed below. Three of each type of key shall be provided with each car. SFMTA will provide details of each type of lock and key.
    a. Crew Key: This key shall enable the master controller and allow access to the vehicle through operation of door key switches, window locks, mechanical locks, and cab door locks, etc.
    b. Maintenance Key: This key shall allow maintenance personnel access to equipment boxes, panels, enclosures, etc.

15.1.8 Passenger Stop Request

1. A passenger stop request system shall be provided to allow passengers to alert the operator to an upcoming stop. In addition, the passenger stop system shall include a push button for wheel chair stop request and an indicator in the cab to inform the operator that a wheel chair stop is required. The pushbutton for the stop request shall be blue and similar to what is currently in use on SFMTA buses.

15.1.9 Bicycle Racks

1. Provision for safe storage of up to 4 bicycles shall be made within the LRV. Locations for these bicycle storage racks are subject to SFMTA approval and shall not be located near or in conflict with the Elderly and Disabled Accessibility locations.

16 NOT USED

17 MONITORING AND DIAGNOSTICS 17-1

17.1 Performance Requirements 17-1

17 MONITORING AND DIAGNOSTICS

17.1 PERFORMANCE REQUIREMENTS

1. The MDS shall have sufficient non-volatile storage to retain all recorded data without overwriting for at least the interval between periodic inspections.

18 SOFTWARE SYSTEMS **18-1**

18.1 Specific Requirements **18-1**

18.1.1 Software Documentation 18-1

18 SOFTWARE SYSTEMS

18.1 SPECIFIC REQUIREMENTS

18.1.1 Software Documentation

1. For custom software, thorough and accurate software documentation submittal and the SFMTA acceptance are required.
2. Software documentation shall be in accordance with IEEE Std 1558-2004, "Standard for Software Documentation for Rail Equipment and Systems" and with the additional requirements in this section.
3. The IEEE Std 1558 requirements shall be for a type 5 procurement type as defined within that standard unless approved by the SFMTA.
4. For "Commercially Available" software, software documentation requirements shall be limited to:
    a. The original data storage/transfer media,
    b. Functional and usage details,
    c. All provider manuals,
    d. Licenses required for SFMTA use.
5. The software details, tools, and documentation specified by this section shall be delivered to the SFMTA prior to the end of the warranty period;
6. Software source code for non-commercially available software shall be provided at the end of the warranty period. Use of Escrow agreements will be accepted.
7. The City shall receive licenses for all software in accordance with Section 26.2 of the Agreement.

19 MATERIALS AND WORKMANSHIP **19-1**

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19.2 Flammability and Smoke Emission Requirements **19-1**

19.2.1 General 19-1

19.2.2 Toxicity 19-1

19.2.3 Electrical Fire Safety 19-1

19 MATERIALS AND WORKMANSHIP

19.1 GENERAL

19.1.1 SFMTA Plan for this Section

1. It is SFMTA's intention that proposers, at the RFP stage, offer their proposed materials and workmanship criteria for review. During negotiations, discussions will be held to establish agreed upon criteria for this section. The agreed language will form the final Section 19 of this document. Appendix B contains suggested standard language for consideration.
2. The specific provisions below are firm requirements.

19.1.2 Prohibited Materials

1. The following materials are prohibited for use in the construction of these cars, except where specifically permitted:
   a. PVC
   b. Asbestos
   c. Lead in brake shoes
   d. Urethane Foam
   e. Cadmium (except for battery)
   f. Aluminum Threaded Fasteners
   g. PCB's
   h. Materials listed in 29 CFR 1910.19

19.2 FLAMMABILITY AND SMOKE EMISSION REQUIREMENTS

19.2.1 General

1. All combustible material used in the construction of the car shall satisfy the flammability, smoke emission, and toxicity requirements, NFPA 130 or a standard approved by the SFMTA.

19.2.2 Toxicity

1. Those materials and products generally recognized to have highly toxic products of combustion shall not be used.

19.2.3 Electrical Fire Safety

1. Electrical equipment, wiring and apparatus shall conform to NFPA 130, Section 8, except where more restrictive requirements are imposed by this Technical Specification.

20 PROGRAM MANAGEMENT AND QUALITY ASSURANCE 20-1

20.1 General 20-1

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20.1.3 Construction Photographs.. 20-1

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20 PROGRAM MANAGEMENT AND QUALITY ASSURANCE

20.1 GENERAL

20.1.1 SFMTA Plan for this Section

1. It is SFMTA's intention that proposers, at the RFP stage, offer their proposed program management and Quality Assurance approaches for review. During negotiations, discussions will be held to establish agreed criteria for this section. The agreed language will form the final Section 20 of this document. Appendix C contains suggested standard language for consideration.
2. Proposers should submit their Program Management Plan in response to the RFP. This submittal will be used to evaluate the value it offers SFMTA and to earn scoring points in the selection process.
3. During negotiations, a Program Management Plan will be jointly developed. This plan will set forth the general principles that will govern the participation of SFMTA, its consultants, and the Contractor throughout the project duration. When complete this Plan will become a part of the Contract.
4. The specific provisions below are firm requirements.

20.1.2 SFMTA Program Management Principles

1. The SFMTA will be involved in all phases of the work to the degree necessary to protect public policy interests in safety, cost, performance, legal, & regulatory compliance.
2. The Contractor will be responsible for all phases of work needed to deliver a safe, timely, and cost effective product that is in compliance with legal, regulatory and performance requirements as called for in the Contract.
3. The following principles illustrate SFMTA's approach to the management of the LRV4 project.
    a. The SFMTA will "accept" or "reject" work products, rather than "approving" such products. This includes designs, materials, analyses, QA/QC plans etc.
    b. SFMTA's role will be to provide oversight of all phases and elements of work. This will not include direct participation in the execution of the Contractors activities, except as required by FTA regulations.
    c. The SFMTA will not assume or acquire the Contractor's responsibilities.
    d. The SFMTA will retain the right to audit any element of work at anytime throughout the duration of the project.
    e. The SFMTA will assist the Contractor where and when able to protect or effect its interests by providing information, opinions, preferences, direction, and decisions as requested by the Contractor.

20.1.3 Construction Photographs

1. The Contractor shall submit to the SFMTA high-resolution digital photographs of the vehicle development, construction, and assembly progress, as well as the finished car.

20.1.4 Mock-up and Samples

1. The Contractor shall provide a full-size mock-up of a complete 1/2 vehicle including and of equipment arrangement details for design reviews. Mock-up shall be updated as necessary.
2. The mock-up shall have all components, hardware and equipment similar or identical in appearance to those to be used on the production vehicle to the greatest extent possible.
3. The mock-up shall show details of:
    a. The front end,
    b. Underfloor equipment arrangement,
    c. Interior and exterior roof-mounted equipment locations,
    d. Roof equipment arrangement,
    e. Articulation,
    f. Cab area.
4. The mock-up shall be finished in appearance, similar to an actual vehicle, and shall have operating exterior and interior lights and one set of operating side doors and moving steps.
5. The roof and undercar mounted equipment mock-up shall show the locations of all equipment including conduits, cable runs and piping.
6. Separate mock-up for roof and undercar equipment locations may be provided.
7. Existing vehicles may be utilized for demonstrating equipment arrangements.
8. The Contractor may alternatively propose, in lieu of the “physically” constructed full-scale equipment layout mock-up, full-scale 3D mock-up constructed with digitally accurate 3D design models. Software and any hardware required for this system and the latest revision of the 3D mock-up shall be available at SFMTA for internal reviews.

20.1.5 As-Built Drawings

1. The Contractor shall provide the SFMTA with As-Built Drawings, including drawings down to the sub assembly level.
    a. As necessary for design review and vehicle maintenance, component level drawings shall also be included.
2. Contractor shall provide drawings in electronic format, fully compatible with AutoCAD, latest version or alternate software to be approved by SFMTA.

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21 REQUIREMENTS MANAGEMENT, DESIGN VALIDATION AND VERIFICATION

21.1 GENERAL

1. This section requires a systematic approach for the Contractor to verify to the SFMTA that each of the requirements contained in the technical specification has been met.
2. Each requirement contained in the Technical Specification is clearly identified with a unique paragraph number tied to where that requirement occurs in the organization of the Technical Specification.
3. Below outlines a high level overview of the verification required by component, system and vehicle. The verification identified in this section is grouped by the following categories, detailed in 21.3:
    a. Design Verification
        i. Component Level
        ii. System Level
        iii. Vehicle Level
    b. Manufacturing Verification
    c. Functional Verification
        i. Component Level
        ii. Vehicle Level
        iii. Acceptance Testing
4. The list above identifies typical verifications to be included in the Requirements Traceability Matrix (RTM).
5. The list above is in no way comprehensive. The Contractor shall develop and submit a comprehensive RTM that proposes a process for the verification of all requirements.
6. Although primarily verification of vehicle requirements, the verification process must include the appropriate verification of all deliverable equipment, including special tools, diagnostic equipment, portable test equipment, and bench test equipment.

21.2 REQUIREMENTS TRACEABILITY MANAGEMENT

21.2.1 General

1. The Contractor shall verify each requirement in this technical specification using the following process:
    a. No more than 90 calendar days after NTP, the Contractor shall develop and submit for review and approval a master RTM that proposes a method of verification of each requirement.
    b. The Contractor shall track and report progress on requirements verification to the SFMTA and submit a revised RTM at 30 day intervals.
    c. No less than 90 calendar days prior to the scheduled date for verification of a requirement, the Contractor shall submit a verification procedure for that

requirement that describes the procedures, instrumentation, calibrations, measurements, tests and inspections to be used/done to accomplish the verification of that requirement.

d. Within 30 calendar days of receiving a requirement verification procedure from the Contractor, the SFMTA shall either approve the plan or inform the contractor of the changes necessary to receive approval.

e. Within 30 calendar days of receiving notification of necessary changes to a verification procedure, the Contractor shall make the changes and resubmit the plan to the transit system for final approval.

f. Using the approved procedures, the Contractor shall conduct the verification of the requirement. The SFMTA has the right to witness all requirement verifications.

g. If the acceptance criteria are not achieved, the Contractor shall make recommendations to the SFMTA on the corrective action to be taken. Within 30 calendar days of receipt of the recommendations, the SFMTA and Contractor will resolve what corrective action to take.

h. After taking the corrective action the Contractor shall repeat the verification of the requirement. If acceptance criteria are not achieved, the steps set forth in Section 21.2.11.g shall be repeated until the acceptance criteria are achieved.

i. No more than 30 calendar days after completing the successful verification of a requirement, the Contractor shall submit a requirement verification report to the SFMTA which clearly states the procedures used, the results of measurements, tests or observations conducted and a comparison of the results to the acceptance criteria for that requirement. The report shall draw a clear conclusion as to the acceptance criteria being achieved.

21.2.2 Requirements Traceability Matrix

1. At a minimum, the RTM shall include the following information:
   a. Subsystem.
   b. Test Type (e.g. LRU Design Verification).
   c. Subject.
   d. Verification method (e.g. analysis, test, etc.).
   e. Test or process number.
   f. Date Performed.
   g. Status (e.g. passed, failed).

21.3 VERIFICATION

21.3.1 General

1. Contractor shall verify requirements through a measurement, a test, analysis, an inspection or by submittal of data obtained through any of these methods from previous procurements.

2. The requirements verification tracking table shall contain a column that describes how each requirement shall be verified.
3. All performed verifications shall be documented in the Requirements Traceability Matrix.
4. Documentation for all verification shall be maintained and made available on request.

21.3.2 Design Verification

21.3.2.1 General Requirements

1. The Contractor shall provide verification that the Contractor's design meets all of the requirements of this technical specification.
2. The Contractor shall successfully verify the design by way of a one-time analysis and test.
3. Verification shall be clearly listed in the Contractor's Requirement Traceability Matrix, which shall be submitted to the SFMTA for approval in accordance with Section 21.2.
4. The Contractor may submit verification of design on the basis of similarity to other projects that the contractor has completed.
5. Acceptance of verification on the basis of similarity will be at the discretion of the SFMTA.

21.3.2.2 Line Replaceable Unit (LRU) Level

1. The Contractor shall verify conformance to specification requirements as well as design parameters to satisfy system level requirements.

21.3.2.3 System Level

1. The Contractor shall verify conformance to specification requirements as well as design parameters to satisfy vehicle level requirements
2. In cases where it is not be feasible to perform an off-vehicle system level test, system level verification will be performed at the vehicle level.

21.3.2.4 Vehicle Level

1. The Contractor shall verify conformance to specification requirements as well as design parameters to satisfy operational level requirements

21.3.3 Manufacturing Verification

1. First Article Inspections (FAI) shall verify that the first item manufactured under the regular production processes and procedures meets the specification and design requirements.
2. Refer to Section 20 for detailed First Article Inspection requirements.

21.3.4 Functional Verification

21.3.4.1 General Requirements

1. The Contractor shall successfully verify by test that the equipment functions as required by the specification and to the final approved design.
2. Verification shall be by way of routine tests conducted at the LRU level or the vehicle level.
3. Verification shall be clearly listed in the Contractor's Requirement Traceability Matrix, which shall be submitted to the SFMTA for approval in accordance with Section 21.2.

21.3.4.2 Line Replaceable Unit (LRU) Level

1. The Contractor shall verify conformance to equipment functions as required by the specification and to the final approved design.
2. LRU level functional verification shall be carried out either at the supplier's facility or at the Contractor's final assembly facility.

21.3.4.3 Vehicle Level

1. The Contractor shall verify conformance to vehicle level operational requirements as required by the specification and to the final approved design.

21.3.4.4 Acceptance Testing

1. The purpose of acceptance verification is to confirm that each vehicle is fully functional, and safe and suitable for service on the SFMTA's system.
2. The Contractor shall submit for review and approval a comprehensive acceptance program.
3. Acceptance verification shall be performed after delivery of each vehicle to the SFMTA's property.
4. The Contractor shall include in the verification matrix all verification necessary for the acceptance of each vehicle.
5. Results of all Acceptance Testing shall be included in each vehicle's VHB

21.3.4.5 Qualification Testing

1. SFMTA does not have a test track and operates mainly in mixed traffic, therefore:
    a. Qualification Testing of the first two (2) vehicles produced shall be at the Contractor's Facility or a location in which qualification through all of the propulsion and braking ranges can be verified and validated;
    b. Qualification Testing for the first vehicle produced shall also include burn-in testing.

21.3.5 System Safety Program Plan

1. The Contractor shall submit for approval a System Safety Program Plan (SSPP) that defines the activities, management controls, and monitoring processes by which the Contractor shall ensure that safety considerations, compatible with other system

requirements, are incorporated into the design of the vehicle to minimize the potential for accidents.

2. The SSPP shall demonstrate that the Contractor has a clear understanding of system safety requirements and has an organization in place that is capable of identifying safety hazards and performing analyses to verify that they have been eliminated or adequately mitigated.

The SSPP shall be structured in accordance with MIL-STD-882, Task 102.

21.3.6 Hazard Categories

This section describes the hazard categories and corresponding acceptable probabilities that Contractor must meet for the design of the vehicle and its systems to be judged safe.

Category I (Catastrophic)

Equipment failures, human errors, and/or external circumstances that result in multiple fatalities, destruction of vehicles, or damage to stations or track segments such that affected segments of the transit system cannot operate for an extended period. Category I hazards result in a major accident or catastrophe, such as destruction of a train with fatalities. Effective or timely corrective action by the train Operator is not realistically possible.

Category II (Critical)

Equipment failures, human errors, and/or external circumstances that result in extensive damage to equipment, physical distress such that train Operators cannot be relied upon to perform their tasks accurately or completely, or adverse effects on the traveling public, including up to a few severe injuries or, exceptionally, a fatality. The train or affected fixed facility is in jeopardy unless proper corrective action occurs quickly enough and is effective enough to prevent the condition from progressing to Category I.

Category III (Marginal)

Equipment failures, human errors, and/or external circumstances that reduce the capability of the transit system or the ability of Operators to cope with adverse operating conditions to the extent that, for example, safety margins or functional capabilities are degraded; equipment sustains non-disabling damage; conditions occur which impair Operator efficiency; or the traveling public experiences some minor injury, discomfort, or danger. Although safety margins may be significantly reduced, for example because of loss of redundancy or forced operation on backup systems, trains, fixed facilities, or personnel are not in immediate danger. A subsequent increase in the severity of the hazard requires an additional failure or gross error by Operators.

Category IV (Negligible)

Equipment failures, human errors, and/or external circumstances that do not significantly reduce safety and that require a response well within the capability of the Operator. Negligible hazards may include, for example, a slight reduction in safety margins or functional capabilities; a temporary and slight increase in Operator workload, such as manual train operation; or some inconvenience to the traveling public. Category IV hazards are considered nuisance events, or at worst, hazards only when coupled with incompetent operation or action.

21.3.6.1 System Safety Criteria

The Contractor shall define design criteria to ensure that system safety objectives are implemented throughout all phases of design development, testing, delivery, operations, and maintenance.

The following criteria, as a minimum, shall be adopted by the Contractor:

1. Potential or actual hazards identified through analyses shall be mitigated in accordance with the following order of precedence:
    a. Use of design techniques
    b. Use of safety devices
    c. Use of warning devices
    d. Use of special procedures.
2. No single-point failure shall result in or produce the potential for a Category I or Category II hazard. Multiple, latent, undetected failure modes shall be considered as a single-point failure.
3. The vehicle design shall incorporate component interlocks wherever an out-of-sequence operation could cause a Category I or Category II hazard.
4. Emergency equipment shall be provided for public use and shall be clearly identified and readily accessible.
5. The following redundancy requirements shall be met:
6. Where redundancy is used in safety-critical areas, there shall be no single-point failure which could result in loss of safety
7. Redundant paths shall not contain a common mode failure
8. Failures in a redundant element or circuit shall be annunciated to the train Operator, or inspection intervals and procedures shall be specified to ensure that both paths are operational.

21.3.6.2 Acceptable Hazard Probability

The Contractor shall implement a process for determining acceptable hazards, based on hazard severity and probability of occurrence. In general, the more severe the hazard, the more unlikely it should be.

For the LRV4, the following requirements have been established:

1. Category I hazards shall not be expected to occur during the entire operational life of the vehicle. Based on the operating hours and life of the base-order fleet, the probability of Category I hazards shall be shown through analysis to be less than 1.0 x 10^{-9} per car-hour of operation for each hazard.
2. Based on the operating hours and life of the base-order fleet, the probability of Category II hazards shall be shown through analysis to be less than 5.0 x 10^{-7} per car-hour of operation for each hazard.
3. Category III hazards shall be resolved using standard fail-safe engineering practices.
4. No special safety measures are required for Category IV hazards.

5. Probabilities shall be based on all sources of the category hazard, not just individual sources.

21.3.7 Safety Analysis

The Contractor shall assess the effect upon safety of maloperation or failure of the vehicle and of vehicle systems, subsystems, and line replaceable units, including their interfaces. The effects of vehicle interfaces with other transit elements such as signaling, facilities, support equipment, operational procedures and environments, and maintenance programs shall be examined. The Contractor is fully responsible for the Integration, Function and Safety of LRV4. During the design phase, the safety analyses performed by the Contractor shall accomplish the following:

1. Identify potential hazards and establish appropriate safety criteria;
2. Assess the design, based on safety criteria;
3. Modify the proposed designs as necessary to satisfy the safety criteria;
4. Demonstrate compliance with the criteria.

21.3.7.1 Preliminary Hazard Analyses

1. The Contractor shall submit for approval a Preliminary Hazard Analysis (PHA). The PHA shall provide a systematic, high-level examination of all proposed system elements in order to identify and classify potential hazards to the overall transit system.
2. The PHA shall address the vulnerability of system functions, rather than assess any particular hardware or software design. The PHA shall be qualitative and shall be conducted using experienced engineering judgment.
3. The PHA shall develop safety design requirements for the system and establish the framework for subsequent safety analyses. It shall provide information about potential hazards and assign a hazard severity category to each.

21.3.7.2 Failure Modes and Effects Analyses

1. The Contractor shall prepare and submit for approval a Failure Modes and Effects Analysis (FMEA). The FMEA shall provide a systematic, comprehensive, bottom-up evaluation that analyzes the effects of potential component failures in a system, as installed, from design data.
2. The FMEA shall assess the impact of failures on subsystem and system operation, and consequently on the operational safety of the transit system. The FMEA shall assess all failures which could cause or contribute to Category I or II hazards.

21.3.7.3 Sneak Circuit Analysis

1. The Contractor shall perform a Sneak Circuit Analysis (SCA) to detect functional and/or Category I or II safety problems that could arise from wiring faults or errors, and shall submit the analysis for approval. The SCA shall ensure that there are no unintended circuit paths that will provide functions other than those intended.
2. The sneak circuit analysis shall be performed for the overall vehicle and shall consider interfaces with subcontractor-supplied equipment and coupler pin assignments.

21.3.7.4 Operating and Support Hazard Analyses

1. The Contractor shall submit for approval an Operating and Support Hazard Analysis (O&SHA). The analysis shall evaluate the operating and maintenance procedures of critical systems to ensure that neither Operator error nor incorrect maintenance gives rise to unwanted system effects. Critical systems are defined as those in which a failure could cause or contribute to a Category I or II hazard.
2. The O&SHA shall be carried out in a similar fashion as the FMEA, except that "tasks" and "error modes" shall be examined instead of "components" and "failure modes." The O&SHA shall be performed during the Preliminary Design Review process so that the results of the analysis can have a meaningful impact on final designs.
3. The O&SHA shall describe the procedure being analyzed and shall identify specific tasks within each procedure that are prone to critical human errors. Each task shall be systematically evaluated to identify potential errors and to assess their effects on the system and transit system. The O&SHA shall provide recommendations for reducing or eliminating the chances of those errors.
4. Any potential Category I and II hazards resolved through procedures shall be cross-referenced between the O&SHA and the appropriate operating or maintenance manuals.

21.3.7.5 Fault Tree Analyses

The Contractor shall perform and submit for approval Fault Tree Analyses (FTAs) that quantify the probability of each Category I and II hazard identified in the PHAs. The FTAs shall consider all interfacing items which in conjunction with the analyzed system could lead to the occurrence of the identified hazard.

21.3.7.6 Hazard Mitigation Traceability Matrix

The Contractor shall develop and maintain a matrix of all Category I and II hazards. The matrix shall describe each hazard and its ultimate resolution, and identify current status. The resolution of each hazard must be verified by identifying a specific drawing, procedure, analysis, or report.

21.3.8 Fire and Life Safety

1. The entire vehicle and its components, subsystems, and systems shall comply with the requirements of NFPA 130. Measures shall be adopted to minimize injury due to fire, smoke, explosion, or panic due to fire. Measures shall also be adopted to protect equipment from damage by fire or explosion.
2. The vehicle shall be designed to prevent penetration of an underfloor or roof fire to the vehicle interior. Fire stops shall be provided at floor and roof penetrations. Equipment shall, whenever practicable, be located outside of the passenger compartment. Enclosures for control and other critical equipment shall provide protection against environmental contamination and mechanical damage.

21.3.9 Safety Certification

The Contractor shall support SFMTA in the Safety Certification process.

21.3.10 Reliability Program

1. The Contractor's reliability program shall be submitted according to Project Delivery Schedule in Agreement Exhibit 3 for the SFMTA's approval, and shall contain the following information, as a minimum:
    a. Reliability program objectives;
    b. Reliability program schedule, which identifies specific tasks, with start and completion dates, and explains how these tasks are coordinated and integrated with major program milestones for design, manufacturing, and testing;
    c. Methodology to be used in reliability analyses to predict compliance with the reliability requirements specified in Sections 2.8.1;
    d. Organization of personnel responsible for managing the reliability program;
    e. Controls for activities of subcontractors and equipment suppliers, to assure their compliance with reliability program methods and objectives;
    f. Preliminary reliability demonstration testing plans for verification of compliance with reliability requirements when calculations and analyses are inconclusive, or when past performance records are incomplete or unavailable; and
    g. Reliability Demonstration Procedures.
2. Reliability progress reporting, which details implementation of the approved reliability program, shall be submitted to the SFMTA on a monthly basis, beginning 30 calendar days after delivery of the first vehicle.

21.3.11 Reliability Demonstration

1. The Contractor shall submit a Reliability Demonstration Plan (RDP) 90 calendar days before delivery of the first car which defines the following for a demonstration to prove compliance with the specified MDBTD and MDBCF requirements and failure definitions in Sections 2.8.1.
    a. Reliability demonstration schedule (including vehicle delivery and burn-in);
    b. Reliability demonstration procedures and forms for recording and submitting data, which shall be approved by the SFMTA before the start of the reliability demonstration;
    c. Success-failure criteria for measuring MDBCF values for individual equipment items and subsystems under demonstration;
    d. Failure analysis of reported failures to identify the cause and need for corrective action. The Contractor shall establish a Failure Review Board to meet as required, to determine by consensus the categorization of failures and the need and depth of failure analyses. The Failure Review Board shall consist of members designated by the Contractor and by the SFMTA. When mutual agreement cannot be negotiated, the SFMTA's position shall prevail;
    e. Change control procedures for implementing design changes during the demonstration program; and
    f. Format and location of test records, test logs, and data records. During the demonstration, the vehicles shall be maintained by the SFMTA's maintenance

personnel according to the approved Maintenance Plan and Maintenance Manuals. The SFMTA shall be responsible for vehicle operating and the conduct of simulated or actual revenue service.

2. If, after the end of the demonstration, it cannot be determined that all of the specified reliability requirements have been met, the Contractor shall re-design, as needed, to achieve acceptable reliability.
3. Acceptable MDBTD data shall be obtained by another demonstration of at least six months duration on the modified vehicles, and the Contractor shall bear all costs associated with the re-design effort, including vehicle modifications and associated costs.

21.3.12 Maintainability Demonstration

1. As part of the training program for maintenance personnel, Contractor shall demonstrate all servicing and preventive maintenance.
2. Contractor shall demonstrate troubleshooting, change out of components, corrective maintenance, and use of special tools where special emphasis, instruction, or proficiency is needed.
3. Contractor shall demonstrate vehicle movement under disabling conditions.
4. The Contractor shall submit a Maintainability Demonstration Plan 90 calendar days before delivery of the first vehicle.

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22 SYSTEM SUPPORT

22.1 GENERAL

1. This section defines vehicle system support requirements that shall be implemented to ensure that the operation, maintenance, and management of the fleet achieves the performance, reliability and availability requirements stated in this specification.
2. System support shall include:
    a. Technical documents,
    b. Training programs,
    c. Spare parts,
    d. Special tools,
    e. Diagnostic test equipment,
    f. Technical support services.

22.2 SPECIFIC REQUIREMENTS

22.2.1 Technical Documents

22.2.1.1 General

1. Documents shall be developed using editable publishing software that is commercially available.
2. Photographs shall be used in lieu of illustrations when applicable and appropriate.
3. Documents and binding method shall be designed for continuous, long-term service in a maintenance shop environment.
4. All printed material shall be clearly reproducible, without loss of resolution when copied using common high-contrast copying machines.
5. The Contractor shall submit a Technical Documents Program Plan
    a. Outlining the methodology, schedule, and deliverables related to the Technical Documents required for the Contract.
    b. Identifying how documents will be reviewed by the Contractor and subcontractor(s).
    c. Specifying the review cycle, including both time intervals and anticipated reviewers for the SFMTA, Contractor, and subcontractors.
    d. Identifying how Service Bulletins and revisions will be identified and distributed.
    e. Providing strategies for repair and replacement, running repair and heavy repair, preventive and corrective maintenance.
6. A Design and Style Guide for all technical documents shall be submitted by the Contractor to the SFMTA no later than 60 calendar days after NTP.
7. Typical SFMTA requirements for technical documents are provided in Appendix D.

8. Contractor shall coordinate development of all technical documents with the Maintainability analyses, if provided.
9. All technical documents shall include any mitigation activities identified in Safety analyses.
10. Target Audience Analysis
    a. The Contractor shall conduct a Target Audience Analysis that shall consider the background, theoretical knowledge and level of proficiency needed by maintenance personnel performing maintenance on new equipment. This analysis shall compare maintenance and operating personnel requirements, which are determined from the needs of the car design, to descriptions of available personnel provided by the SFMTA.
    b. Special consideration shall be given to the skills and knowledge required to operate and maintain unit equipment of a design or function new to SFMTA, and to all special tools and test equipment specific to, or being delivered with, this equipment. The gap between current and newly- required skills and knowledge can be expected to be larger in the area of new unit equipment and special tools and test equipment. These deficiencies shall be enumerated by the Contractor in the approved Target Audience Analysis.
    c. In the Contractor's Target Audience Analysis Report, all tasks on the Maintenance Allocation Chart (MAC) shall be sorted by craft. Each task group shall be analyzed to identify all specific, new skills and knowledge that shall be required of the craft. The report shall identify specific gaps between existing and required knowledge. Tasks that identify training shall be identified here and designated on the MAC. The Manuals and Training materials shall be written based on the Target Audience Analysis Report.

22.2.1.2 Operator's Manual

1. The Operator's Manual shall contain all information required for safe and efficient operation of the LRV, including the following:
    a. A general description to familiarize the reader with the basic components and features of the vehicle,
    b. Location, function, and operation of all:
        i. Controls,
        ii. Gauges,
        iii. Indicators,
        iv. Switches.
    c. Procedures to prepare the vehicle for operation,
    d. Procedures to operate the vehicle,
    e. Procedures to secure the vehicle from operation,
    f. Emergency procedures,
    g. Safety-related notes, cautions, and warnings,
    h. Trouble symptoms and diagnostic methods that allow the operator to recover the vehicle during a failure or other incident,

    i. Other features of the vehicle for which the operator should have some basic knowledge even if operator may not be in a position to control or adjust.

2. The Operator's Manual shall be pocket-sized.
    a. The Contractor shall submit proposed size to the SFMTA for review and approval.
3. Submittals and schedule for their delivery are listed in Section 22.2.5

22.2.1.3 Running Maintenance Manual

1. The SFMTA shall confirm the scope of work to be covered in the Running Maintenance Manual (RMM). However, at a minimum, the RMM shall cover all running maintenance, and other maintenance not requiring more than two hours elapsed time.
2. The organization of the maintenance manuals shall treat the vehicle as an integrated system, not as a grouping of disassociated parts.
3. Contractor and Sub-contractor information shall be integrated into a unified presentation for each system addressed.
4. The RMM shall contain:
    a. An overview of the vehicle operation,
    b. Both general and detailed descriptions of each:
        i. System;
        ii. Subsystem;
        iii. Major component of the vehicle.
    c. The recommended schedule for the performance of all preventive maintenance procedures and shall include the frequency, tools, and materials required for each procedure;
    d. Corrective Maintenance (Running Repair) - Shall include step-by-step removal, replacement and adjustment procedures to the line replaceable unit (LRU);
    e. Troubleshooting - Shall include a list in tabular format of symptoms, causes of malfunction or improper operation, and probable remedies to the LRUs;
    f. Inspection procedures, intervals, and criteria.
5. The RMM shall include a Scheduled and Preventive Maintenance Plan - Routine test, service and adjust
    a. The Scheduled and Preventive Maintenance Plan shall identify all of the scheduled maintenance tasks to be performed and the intervals at which they need to be scheduled, including SFMTA-mandated daily and periodic inspections.
    b. The Scheduled and Preventive Maintenance Plan shall outline all maintenance tasks required to keep the car in service during the operating period between scheduled maintenances and the person-hours required to perform each task.

i. All service intervals up to vehicle overhaul shall be included. Additional or extended maintenance intervals may be presented at the discretion of the Contractor and with the approval of the SFMTA.

ii. During the development of the scheduled/preventive maintenance plan, Contractor should give consideration to service intervals of components and sub-systems that would require the disassembly and/or removal of other components or sub-components that recently required similar maintenance or would require such maintenance in the near future.

6. The Contractor shall make every effort to minimize redundant or related maintenance activity to optimize the maintenance effort and out-of-service time. Any remaining service interval conflicts that cannot be resolved by the Contractor will be reviewed with the SFMTA in an attempt to resolve possible duplication of disassembly, maintenance, and assembly of these components and sub-systems.
7. The use of Diagnostic Test Equipment (DTE), where applicable, shall be integrated into the appropriate section. The DTE shall not be added in as a stand-alone manual, but integrated as a tool to be used within documented maintenance procedures.
8. Submittals and schedule for their delivery are listed in Section 22.2.5.

22.2.1.4 Heavy Repair and Overhaul Manual

1. Heavy Repair and Overhaul, for the purposes of this Specification, is defined as maintenance up to and including major component overhaul, not included in the Running Repair Manual. Heavy maintenance tasks will generally, but not necessarily, require more than two hours elapsed time to complete
2. The HRM shall allow maintenance personnel to effectively:
   a. Service,
   b. Inspect,
   c. Troubleshoot,
   d. Repair,
   e. Replace,
   f. Adjust,
   g. Overhaul each component, system and subsystem of the vehicle.
3. The manual shall provide criteria explaining when maintenance personnel should replace, rather than repair, a major component or subsystem, including condemning limits, adjustments and any other information necessary to maintain the vehicle.
4. The manual shall include a recommended schedule for the performance of all maintenance procedures and shall include the frequency, tools, and materials required for each procedure.
5. The HRM shall provide detailed troubleshooting procedures for the sub-assemblies as well as complete assemblies, and shall include step-by-step removal, overhaul, replacement, and adjustment procedures to the smallest repairable component.
6. Detailed test and adjustment procedures shall be provided for all sub-assemblies and for complete assemblies or units.

7. As part of the overhaul procedure, the HRM shall include details for rebuilding, reclaiming, or replacing all wearing or moving parts, with comprehensive information on the limits and tolerances sufficient to enable the SFMTA to determine the best approach to follow.
8. The HRM shall include complete instructions and procedures for the use of special tools including test benches.
9. Submittals and schedule for their delivery are listed in Section 22.2.5.

22.2.1.5 Illustrated Parts Catalog

1. Contractor and Sub-contractor supplied information shall be integrated into a unified presentation for each system addressed.
2. The Illustrated Parts Catalog (IPC) shall identify and describe every component with its related parts, including:
    a. The OEM name and part number,
    b. The Contractor's part number,
    c. Quantities per assembly.
3. Diagrams, cutaways, and exploded drawings shall be used to identify and index every removable/replaceable part.
4. Each illustration shall be accompanied by a corresponding page listing every item in the associated diagram and providing complete ordering data for every item.
5. A part common to different components shall have the same OEM part number and, except for common hardware, cross-references shall be provided to other components in which the part is found.
6. Space shall be provided for separate Sub-Contractor part number.
7. Each part or component shall be associated with the next larger assembly by using an indented format.
8. The IPC shall be organized by the same chapter and system as the RMM and the HRM.
9. The IPC shall include separate sections for test equipment, portable and bench, and special tools supplied under the Contract.
10. Descriptions of parts, including size, material, and grade in the IPC shall be adequate to enable SFMTA to procure the parts independently.
11. The IPC shall include an appendix giving each system's OEM name, address, and telephone number for parts ordering.

22.2.1.6 Integrated Schematics

1. The Integrated Schematic (IS) shall be one which can be readily followed by anyone with basic electrical, pneumatic or hydraulic knowledge, as appropriate.
2. The IS shall be provided in both paper and electronic formats as approved by the SFMTA. The electronic format shall be fully searchable.
3. All necessary information to troubleshoot faults shall be provided on a single diagram, i.e.:

   a. Wire number,
   b. Terminal number,
   c. Component identification,
   d. Alphanumeric grid location for diagram-to-diagram reference,
   e. Other standard identification information.
4. The IS shall be clear and comprehensive and shall provide ample and detailed data that shall allow the SFMTA's vehicle maintenance personnel to troubleshoot and repair a problem down to a LRU.
5. The IS shall contain wiring connection diagrams including:
   a. Wire code (schematic designation),
   b. Origin (FROM device and terminal),
   c. Destination (TO device and terminal),
   d. Wire size,
   e. Voltage rating,
   f. Jacket color,
   g. Harness designation.
   h. All electrical devices,
   i. Electro-pneumatic/hydraulic apparatus,
   j. All microprocessor circuits,
   k. Test points.
6. The IS shall be fully indexed and cross-referenced to enable locating any device or wire number or terminal point between each drawing schematic and part number.
7. All schematic drawings shall be printed on 11-in. x 17-in. sheets for issuance to SFMTA personnel. All text and other items on the drawings shall be clearly legible on the 11-in. by 17-in. sheets.
8. The IS diagrams shall include the following items:
   a. Device symbols table,
   b. Acronym and a cross-reference table providing acronym, equipment name and location by zone,
   c. Trainline wiring diagrams with connector and wire designations,
   d. Equipment arrangement drawing,
   e. Pin-to-pin connector terminal designations and wire designations at both sides of each connection for connectors and terminal blocks,
   f. Power distribution diagrams for:
      i. Primary;
      ii. Auxiliary;
      iii. Low-voltage power.
   g. Wiring diagrams for each subsystem;
   h. Printed circuit board connections and pin-outs for each subsystem;
   i. Point-to-point signal data for troubleshooting;

j. Electric coupler pin arrangement drawing with table identifying the pin number and its corresponding trainline name and the vehicle to coupler connector pin number;
k. Pneumatic diagram;
l. Hydraulic diagram;
m. Refrigerant diagram.

9. The remainder of the IS shall be grouped into subsections.
   a. The subsections shall be divided as much as possible around the major systems.
   b. All subsection sheets shall have an identifiable grid or zone system that allows easy referencing from one subsection page to another.
10. All signals that leave a page or come from another page shall show the destination or origination page.
11. Electronic LRUs shall be shown as empty boxes with the LRU schematic drawing number shown.
12. To the extent possible, where I/O of an LRU can be represented as a relay contact or relay coil it shall be done to facilitate the tracing of signals through the LRU equipment.
13. Graphic symbols for components, devices, and circuits shall conform to:
   a. IEEE STD 315
   b. ANSI Y32
   c. ASME Y14

22.2.2 As-Built Drawings

1. As-built drawings shall be provided as required by Section 20.1.5.

22.2.3 Vehicle History Books

1. A Vehicle History Book shall be provided for each car and shall record the following information:
   a. Vehicle Number and Class
   b. Written report of each test performed on the vehicle or its apparatus.
   c. Serial numbers of all wheels, axles, motors and all other apparatus with serial numbers on the car.
   d. Vehicle weight report, including:
      i. Overall weight;
      ii. Weight at each wheel (first car only);
      iii. Weight at each axle (first car only);
      iv. For serial cars, provide overall LRV weight and weight of trucks.
   e. Wheel and axle mounting records
   f. Modifications
   g. Defects/Disposition and Repairs

h. All vehicle, component and sub-component certifications (i.e. pressure test of air tanks)

2. The format of the Vehicle History Books shall be agreed upon jointly by the Contractor and the SFMTA.
3. It shall be the responsibility of the Contractor to employ an acceptable system of configuration control in keeping individual Vehicle History Books current.
4. The Vehicle History Book for each car shall be turned over to the SFMTA at the successful completion of conditional acceptance testing for that car and shall be updated by the Contractor until the end of warranty.

22.2.4 Diagnostic Test Equipment Manual

1. The Diagnostic Test Equipment Manual (DTEM) shall be provided to address all portable and bench test equipment, along with special tools, furnished under the Contract.
2. Each piece of test equipment shall include operating and maintenance documentation, including:
    a. Complete diagrams,
    b. Schematics,
    c. Maintenance instructions for the device itself,
    d. Calibration instructions for the device itself,
    e. Troubleshooting and repair instructions for the device,
    f. General instructions on use of the device.

22.2.5 Technical Document Schedule of Submittals

1. Refer to Agreement, Exhibit 3 for delivery schedule.
2. The Contractor shall provide, at a minimum, annual updates to the documents described in this section through the life of the Contract.
3. The Contractor shall provide Service Bulletins between document updates for corrections and changes.
4. The Contractor shall provide a form for the SFMTA to report errors, procedures changes, etc.
5. The Technical Documents shall be uniquely identified, including revision level and date of revision on each page. The Technical documents shall be subject to configuration control.

22.2.6 Training

22.2.6.1 General

1. The Contractor shall establish and maintain procedures to identify training needs as necessary to complete work successfully under this Contract.
2. Records of training needs and training completed shall be maintained.

3. The program shall include both formal and informal instructions using such training aids as PowerPoint presentations, mock-up, parts catalogs, videos, manuals, diagrams, CD-ROMs, etc., as may be appropriate to the subject. Slides and transparencies shall not be acceptable as visual training aids.
4. The training program shall include written examination or “hands-on” demonstration, as appropriate, to certify that each of the employees has the knowledge and skills necessary to perform the tasks to which they have been assigned.
5. The Contractor shall submit their proposed training program, including sub-component system training for review and acceptance. The Plan shall identify
    a. The general topics to be taught,
    b. The order in which modules shall be presented,
    c. Each module of instruction,
    d. The proposed schedule for instruction and training.
6. The Contractor shall prepare and submit to the SFMTA for review and approval a training schedule to be performed coincident with the delivery of the first vehicles.
7. The Contractor shall be responsible for providing all test equipment, diagnostic equipment, component parts, and special tools during the training program.
8. The Contractor shall be responsible for preparing copies of all manuals, drawings, schematics, troubleshooting guides, and other handouts for distribution to all students.
9. In addition to the initial training classes, the Contractor shall provide for one class per year through the warranty period, as well as classes for major modifications and field retrofits.
10. Sixty calendar days prior to the initiation of classroom instruction, all instructors shall attend a one-day orientation at the SFMTA’s facility to become familiar with the SFMTA’s safety regulations and facilities, and to be advised of student qualifications and expectations.
11. All training materials, such as training aids and lesson plans, shall become the property of the SFMTA at the completion of the training program.
12. The Contractor shall be responsible for the condition of all training materials for the duration of the training program, and shall replace all damaged materials unless the damage resulted from neglect by the SFMTA.

22.2.6.2 Intent

1. The Contractor shall assume that maintenance/operating personnel have no knowledge of the new vehicles, but have the skills required for their level of employment classification.
2. The Contractor shall design the instruction program to bring up the level of knowledge to perform the required maintenance procedures to ensure that:
    a. The vehicles will operate safely,
    b. Preventive maintenance requirements are understood,
    c. The vehicles remain attractive to customers, both in appearance and function,
    d. The reliability of the vehicles is maintained,

e. Attendance at the program will include supervisory, operating, and maintenance personnel.

22.2.6.3 Program Content

1. The program shall cover scheduled/periodic maintenance, corrective maintenance, trouble-shooting, and heavy maintenance.
2. As a general guide, the program should be broken down into roughly three-quarter classroom and one-quarter hands-on training.
3. The program shall also include in-depth instruction covering all systems and sub-system on the vehicles, as well as general trouble-shooting techniques.
4. The first class shall be video recorded in as mutually agreed between the SFMTA and the Contractor.

22.2.6.4 Subject Content

1. Classroom instruction shall include both the design and function of the systems, components, and parts under discussion.
2. The program shall, at a minimum, include scheduled maintenance, including lubrication schedules, adjustments, consumable replacement, inspection and test frequency, trouble-shooting, removal, and replacement.
3. Classroom instruction shall include the use and maintenance of Diagnostic Test Equipment.

22.2.6.5 Facilities

1. The formal classroom instruction will be conducted in a suitable classroom furnished by the SFMTA in their facilities.
2. Informal field instruction may also be carried out in and around the cars at any of several maintenance facilities
3. The Contractor shall provide the following as part of the Training deliverables:
    a. Full training mock-up for door and step system with door leafs for class use;
    b. Any other training mockups that the Contractor feels will aid in achieving the training objectives.

22.2.6.6 SFMTA Cooperation

1. The SFMTA will lend its fullest cooperation to the carrying out of the program.
2. However the times and duration of the instruction period and the number of personnel available to attend class, must necessarily be at the discretion of the SFMTA.

22.2.6.7 Student Availability

1. The following numbers are furnished as a guide to the magnitude of effort required:
    a. Trainers: 20
    b. Supervisors: 17
    c. Maintenance Staff: 225
    d. Operators: 240

2. The Contractor shall work with the SFMTA to develop a mutually agreeable training schedule that will not unduly affect the ability of the SFMTA to deliver service.

22.2.7 Technical Support

22.2.7.1 Site Support

1. The Contractor's Product Support/SFMTA Service team at the SFMTA's facility shall be responsible for:
   a. Vehicle inspections,
   b. Product Introduction/Testing and Commissioning,
   c. Warranty Administration,
   d. Control of field modifications,
   e. Procurement of materials required for modifications once the manufacturing activities are completed in the plant(s),
   f. Coordination of site testing activities,
   g. Execution of site required tests,
   h. Management of site open items,
   i. Technical support to the SFMTA's personnel,
   j. Material Administration,
   k. Daily meeting to review any outstanding issues on the vehicles,
   l. Weekly open item meetings are held to discuss/resolve any technical/design issues.
2. Contractor shall station technical support personnel shall be stationed at the SFMTA maintenance facility from the time the first vehicle is delivered through the end of the warranty period on the last vehicle delivered.
3. Contractor shall also make periodic support shall also be available before the first vehicle is delivered to enable vehicle facilities criteria to be coordinated with vehicle requirements.
4. The Contractor shall provide additional technical assistance/support as required for any systems or components that are not of service-proven design.

22.2.7.2 On-Site Personnel

1. On-site Contractor personnel qualified to maintain the vehicles shall assist with testing and with resolving operational and maintenance problems.
2. These personnel shall:
   a. Be thoroughly familiar with the operation of the vehicles,
   b. Provide support during the warranty period by isolating failures,
   c. Provide replacement parts and respond to any warranty claims, including initiation and follow-up of remedial actions,
   d. Include field service engineers, technicians, and repair personnel as required,
   e. Be fluent in the English language and fully familiar with all vehicle systems.

3. At least two technicians shall be on-site full time during the warranty period.
4. Contractor shall submit detailed résumés of the proposed support personnel to the SFMTA for approval.

22.2.7.3 On-Call Personnel

1. During vehicle testing on SFMTA's property and during the warranty period, additional on-call personnel shall be on SFMTA's property within two working days of a request to the Contractor for additional technical assistance, for resolution of warranty-related repairs, or for investigation of repetitive failure or design defects.

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23 OWNER DEFINED EQUIPMENT

23.1 GENERAL

1. This section provides requirements for equipment which is defined by the SFMTA and supplied, installed and tested by Contractor.

2. The LRV4 vehicle must interface and operate with certain systems already in place within the SFMTA LRT system. It is the responsibility of the Contractor to design, integrate, provide, and test equipment which is compatible with the current system in place at time of delivery.

23.2 NOT USED

23.3 OWNER DEFINED EQUIPMENT

1. General

   a. Contractor shall supply, install and test SFMTA defined systems as specified below including to train control, fare systems and communications.

23.3.1 Fare Collection

1. Contractor shall supply and install a fare collection system compatible with the SFMTA LRT system per Section 23.1.2. Table below shows the current equipment on the existing fleet.

Table 23-1 Fare Collection

No.	Defined System	Equipment	Qty	Current Location
1-1	Fare Collection	Farebox	2	One in each cab
1-2		Drivers Console	2	One in each cab
1-3		Passenger Device	4	Two in each carbody half
1-4		Power Module	2	One for each carbody half

23.3.2 Signal System

1. Contractor shall supply and install a signal system compatible with the SFMTA LRT system per Section 23.1.2. Table below shows the current equipment on the existing fleet.

Table 23-2 Signal System

No.	Defined System	Equipment	Qty	Current Location
2-1	Signal System	Control Box	2	One in each cab
2-2		Transponder	2	One underneath each cab

23.3.3 Radio (Voice and Data)

1. Contractor shall supply and install a radio system compatible with the SFMTA LRT system per Section 23.1.2. Table below shows the equipment currently being designed for the SFMTA as part of the radio replacement for the entire system.

Table 23-3 Radio

No.	Defined System	Equipment	Qty	Current Location
3-1	Radio (Voice and Data)	Radio	1	One in cabinet located in the middle of the car
3-2		Drivers Control Unit	2	One in each cab
3-3		Vehicle Logic Unit	1	
3-4		Bulk Data Wireless Transfer Unit	1	
3-5		DVAS	1	
3-6		Mobile Access Router / Switch	1	
3-7		Ethernet Switch	1	
3-8		Antennas	4	
3-9		Speed Sensors	1	
3-10		Switch Box	1	
3-11		Serial to Parallel Converter	1	

23.3.4 CCTV

1. Contractor shall supply and install a CCTV system compatible with the SFMTA LRT system per Section 23.1.2. Table below shows the current equipment on the existing fleet.

Table 23-4 CCTV

No.	Defined System	Equipment	Qty	Current Location
4-1	CCTV	Digital Video Recorder	1	One in middle of the car
4-2		Camera (analog)	6	Four in exterior, two in interior
4-3		Camera (IP)	10	Ten in interior
4-4		POE Switch	2	
4-5		Wireless Bridge	1	
4-6		Antenna	3	Three on Roof
4-7		Power Module	1	
4-8		Microphone	2	Two in interior
4-9		Camera Mount Plate	1	
4-10		Camera Brackets	1	
4-11		Drivers Module	2	One in each cab

23.4 SPECIFIC REQUIREMENTS

23.4.1 Design Review

1. The Contractor shall be responsible for integrating all SFMTA defined equipment into the vehicles.

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APPENDIX A – EXISTING SYSTEM INFORMATION

A.1 WAYSIDE CHARACTERISTICS

The vehicle shall be designed for normal operation within the following wayside characteristics and constraints.

A.1.1 Track

The vehicle shall be designed for normal operation with no interferences over all track on the MUNI Metro system, which has the following general characteristics:

(a) Track gauge		4 ft., 8 $^1/_2$ in.
(b) Minimum lateral radius (to centerline)		45 ft., 0 in.
(c) Maximum superelevation		0 ft., 6 in.
(d) Minimum vertical radius, crest		310 ft., 0 in.
(e) Minimum vertical radius, sag		460 ft., 0 in.
(g) Maximum grade		9 percent
(h) Minimum combined lateral and vertical radius		
	Lateral	45 ft., 0 in.
	Vertical	410 ft., 0 in.

The MUNI Metro system incorporates both AREA and street railway type trackwork. The street railway trackwork includes such features as flange-bearing special work and single point turnouts.

The standard rail for all new tee rail track construction is 100 lb/yd ARA-B in mainline track and 90 lb/yd RA-A in yard track. The standard rails for all new girder rail track construction are 128 and 149 lb/yd RE-7A. Girder rail is used only where the system operates within paved streets. The 128 lb/yd RE girder rail is used on tangent track, and the 149 lb/yd RE girder-grooved rail is used as the inside rail on tight-radius curved track.

A.1.2 Structures

(a) Station platform height from top of rail		2 ft., 9 in.
(b) Distance, centerline track to finished edge of platform		4 ft., 8 in.
(c) Station platform length	(minimum)	300 ft., 0 in.
	(maximum)	400 ft., 0 in.

A.2 Current System Configuration

Current Equipment for SFMTA defined systems are listed in the following Table.

Table A.2-1 Current System Configuration for LRV

No	Defined System	Current Manufacturer	Current Model / Part Number / Information	Qty	Current Location
1-1	Fare Collection - Farebox	Cubic	827-1900-9	2	One in each cab
1-2	Fare Collection – Clipper Unit	Cubic/ERG	Driver's Console: ERG p/n DC4700.AAAA	2	One in each cab.
1-3			Passenger Device: ERG p/n 18186	4	Two in each carbody half.
1-4			DC-DC Converter: Schock p/n SDC144.1	2	One for each carbody half.
2	Signal System	Thales			
2-1	Train to Wayside	Vetag	Code Control Box: Vecom p/n 28846134	2	One in each cab.
2-2			Transponder: Vecom p/n 28836221	2	One underneath each cab.
3-1	Radio (voice and data)	Harris OpenSky II	M7300	1	cabinet located in the middle of the car
3-2	Driver control unit	ACS (Harris contract)	Xerox OrbStar 8400 MDT	2	One in each cab
3-3	Vehicle Logic unit	ACS (Harris contract)	Xerox IVU-3100	1	
3-4	Bulk Data wireless transfer unit		5.9 GHz GSRC radio	1	
3-5	DVAS system	Xerox	CCP, AVA Card, PA Amp, Audio Switch, 2 Phones, Cabling, 4 Next Stop Signs, AGC Microphone and 4 internal signs/bracket	1	
3-6	Mobile Access Router/switch	Cisco	10 ports with LTE	1	

No	Defined System	Current Manufacturer	Current Model / Part Number / Information	Qty	Current Location
3-7	LNX-500 Ethernet Switch			1	
3-8	Antennas		GPS, 700/800 MHz, 5.9 GHz, DSRC	1ea	
3-9	Speed Sensors	GE-Wabtec	Cable from gear box to IVU	1	
3-10	Switchbox	Xerox		1	Cabin A/B
3-11	Serial to Parallel Converter			1	
4-1	Digital Video Recorder	DTI	16 Channel DVR Dual Drive Unit	1	One in middle of the car
4-2	Camera (analog)	DTI	Mini Dome Camera Part No 1ZE0280	6	Four in exterior, two in interior
4-3	Camera (IP)	DTI	IP Camera Part No 1ZE0265	10	Ten in interior
4-4	POE Switch	KRATOS	POE Switch, 8-Port KTOS LNP-800AGH-24	2	
4-5	Wireless Bridge	Firetide	4.9GHZ Wireless Bridge 7010	1	
4-6	Antenna	MP Antenna	4.9GHz Antenna 08-ANT-0937	2	Roof
4-6	Antenna		GPS	1	Roof
4-7	Power Module	Kratos	DVS Enclosure Kit ENC-DTI-SF-XXX (Custom Part for each Vehicle Manufacturer)	1	
4-8	Microphone	Kratos	Microphone KTOS-MIC2688	2	Two in interior
4-9	Camera Mount Plate	Kratos	Camera Mounting Plate KTOS-CMP-001	1	
4-10	Camera Brackets	Kratos	Camera Brackets KTOS-CMB-XXX	1	
4-11	Drivers Module		Status Tag Module	2	One in each cab

A.3 Contract Drawings

The following drawings are provided for information. However the Contractor is required to verify existing conditions to ensure worst case conditions are identified and addressed in the design of the LRV, including actual conditions.

1. Sample Design Criteria (Church and Duboce Design Criteria)
   This is a sample track design criteria for SFMTA. Contractor shall work closely with SFMTA for latest information regarding the design criteria.

2. LRV Dynamic Envelope
   The current dynamic envelope diagram for SFMTA is provided. Per Section 2.2.6.2, it is Contractor's responsibility to verify the dynamic envelope.

3. LRV System Outline
   The Muni Metro System details are provided here including System Diagram, substations, track tables, track drawings, and sample horizontal and vertical track tables. Contractor shall work closely with SFMTA for latest information regarding the design criteria.

4. ATCS LRV2 On-Board Equipment
   This document provides details of the current on-board ATC equipment. Contractor shall work closely with SFMTA for latest information regarding the specification.

5. Radio System
   SFMTA is in the process of replacing their entire radio system. This document provides details of new radio system currently being designed for the SFMTA. Contractor shall work closely with SFMTA for latest information regarding the equipment.

6. CCTV Device Layout
   This document provides details of the current CCTV system on the LRV fleet. Contractor shall work closely with SFMTA for latest information regarding the layout.

1. Sample Design Criteria
(Church and Duboce Design Criteria)

12.0 DESIGN CRITERIA

12.1 Trackwork

The trackway design criteria shall be based on the following standard references:

- Local, state and federal laws and regulations
- Muni track design standards
- Industry guidelines (i.e. AREMA Manual of Railway Engineering)
- City & County of San Francisco (CCSF) utility standards
- American Public Transit Association (APTA) publications
- Private utilities standards, where applicable
- DPW Standard Specifications
- Federal Transportation Authority Noise and Vibration Criteria

1. Speed Limit – LRV shall travel at the legal speed limit of parallel traffic.

2. Track Support System – The trackway support structure should be designed to provide adequate support to the trackway superstructure over the anticipated life of the structure. Transition connections between trackway placed on subgrade of different strengths must be designed to anticipate possible differential settlement.

3. Rails – Ri60N rail shall be used in all embedded tracks, except for curves that are less than 300 ft radius. 115RE high strength/premium tee rail shall be used for all running and restraining rails for embedded tracks with curves that are less than 300 ft radius. Furthermore, 115 RE high strength/premium tee rail shall be used for non-embedded tracks

   Restraining rail shall be installed continuous along each embedded tee rail.

4. Trackway Alignment

   The track alignment and clearance will be determined by the parameters contained in this section to achieve the following objective:

   - Patron Comfort & Safety
   - System Safety
   - Operational Efficiency
   - Compatibility with the Characteristics of the Vehicle to be Used
   - Minimize Wear on Rails and LRVs
   - CPUC General Order No. 143B, "Safety Rules and Regulations Governing Light Rail Transit"

   4.1 **Horizontal Alignment** – The horizontal alignment shall be designed to maximize the running speed of LRVs. Superelevation shall be used to minimize wear on the rails where it does not interfere with street grades on shared right-of-ways. The balance speed for superelevation shall be based on the probable speed of the LRV taking into account speed restrictions, stop locations, pedestrian activities and other related parameters.

4.1.1 Horizontal Control – Horizontal control for track alignment shall be referenced to survey control points established for this project. The coordinates for control points are based on the California Coordinate System Zone III, using ground distances.

4.1.2 Tangent Section – The minimum length of tangent track between reverse curves should be 25 ft. The horizontal and vertical alignment should be tangent at station platforms throughout the entire length. A tangent should extend a minimum of 20 ft beyond either end of the platform, unless it can be demonstrated that the swept-path of the LRV will not endanger people or interfere with platform and doors will meet ADA requirements.

4.1.3 Nomenclature and Definition:

E(in): Actual Superelevation – The height by which the outside rail is raised above the inside rail.

E_e(in): Equilibrium Superelevation – The value of superelevation that eliminates lateral forces at a given vehicle speed.

L_c(ft): Arc Length of Circular Curve, measured at track centerline.

L_s(ft): Length of Spiral, measured at track centerline.

$L_{s\,min}$(ft): Minimum Length of Spiral, measured at track centerline.

L_t(ft): Length of Tangent.

R_c(ft): Radius of Circular Curve, measured at track centerline.

R_{min} (ft):	Absolute minimum radius of track centerline shall be 45 ft.
Θ_c:	Center angle of circular curve, radians.
Θs:	Central angle of spiral length L_s, radians.
Θ:	Deflection angle for distance l on spiral, radians.
U (in):	Unbalanced superelevation. The difference between E_e and E.
V (mph):	Probable LRV operating speed.
V_{max} (mph):	The maximum permissible speed of an LRV on the alignment unconstrained by traffic regulations and signals, scheduled stops and comfort requirements.

4.1.4 Circular Curves – Circular curves shall have spiral transitions wherever feasible. Circular curves shall be specified by the centerline radius (R_c), the center angle (Θ_c) and the arc length (L_c). The radius should be as large as possible within the physical restrictions.

4.1.5 Superelevation – Superelevation shall be designed to minimize the wear of the rails (unbalanced superelevation). For shared right-of-way, the maximum track superelevation shall be 2 in. Superelevation shall transition uniformly. Superelevation shall be accomplished by maintaining average of the tops of both rails at the profile grade, raising the outside rail by an amount equal to one-half the superelevation. However, superelevation in paved areas may be accomplished by either lowering the inside rail or raising the outside rail the full amount of the superelevation if it will provide better drainage or better conform to adjacent paved areas. Maximum rate of superelevation runoff shall not exceed 2 inches in 25 ft. The equilibrium superelevation shall be determined to the nearest 0.25 in by the following formula:

$$E_q = E + U = 4.0V^2/R_c$$

where E_q = Equilibrium superelevation in inches
U = Unbalanced Superelevation
Maximum recommended is 3.0"

Maximum permissible is 4.5"
E = Actual superelevation, in inches
R_c = Radius of curvature in ft
V = Probable speed in mph

4.1.6 Spiral – When the geometry allows, spiral curves are used to provide a smooth transition between tangent and curved track and between curves of different radii, thereby increasing rider comfort and minimizing rail wear. Spirals shall be 25ft minimum in length and satisfy the following requirements:

(a) Spiral Curves shall be Barnett spirals.

(b) $V = \sqrt{(E+U)\,Rc/4}$ where

U = Unbalanced Superelevation
Maximum recommended is 3.0"
Maximum permissible is 4.5"
E = Actual superelevation, in inches
R_c = Radius of circular curve, in ft
V = Probable LRV operating speed, in mph

(c) The recommended minimum lengths of spiral curve shall be the greatest of the following:

$L_s = 1.0EV$
$L_s = 1.0UV$ where L_s is in ft
E and U are in inches
V is in mph

(d) The absolute minimum length of a spiral curve shall be the greatest of the following:

$L_{s\,min} = 0.75EV_{max}$
$L_{s\,min} = 0.5UV_{max}$
$L_{s\,min} = 12.5E$ where L_s is in ft
E and U are in inches
V_{max} is in mph

(e) The basic equations defining the spiral are as follows:

$L_s = 2R_c\Theta_s$
$\Theta = (l/L_s)^2\Theta_s$

If $L_s/R_c <= 0.01$ or $L_s < 25$ft, then no spiral is required.

Where

Θ_s	=	central angle of spiral length L_s, radians
Θ	=	deflection angle for spiral length l, radians
l	=	spiral length between any two points on spiral (ft)
R_c	=	radius of circular curve (ft)
L_s	=	total length of spiral (ft)

4.2 Vertical Alignment

4.2.1 Introduction – Track shall conform to street surface profile grades unless otherwise revised for new street grades, or as needed to clear underground facilities. The profile grade is defined as the average of the elevations of both tops of rails of the same track.

4.2.2 Nomenclature and Definition

G (%):	Vertical grade
ΔG (%):	Change in grade over the length of the vertical curve
Δg (%):	The rate of change of vertical grade, i.e., the change of vertical grade in a 100-foot station
Δg_{max} (%):	See 4.2.4.
LVC (ft):	The length of the vertical curve

4.2.3 Maximum/Minimum Gradients

The desired grade is less than 5 percent. The maximum grade allowed shall be 7 percent. This may be increased up to 9 percent for very short distances.

A minimum grade of 0.3 percent is required for drainage.

4.2.4 Vertical Curves

Vertical curves shall be parabolic curves having a constant rate of change or grade. The minimum radius of vertical crest curve and a sag curve shall be within the requirements of the selected vehicle. The absolute minimum curve length is 40 ft. Vertical curves shall end at 25ft away from a stop unless it can be demonstrated that the vehicle doors will meet ADA requirements.

1. The minimum length of vertical curve shall be the greater of:

   (a) $LVC_{min} = \Delta G/\Delta g_{max} * 100$
   (b) $LVC_{min} = 15 * \Delta G$

2. Where possible, the maximum rate of change of vertical grade shall be as follows:

   (a) For vertical curve crest on tangent $\Delta g_{max} = 3000/V^2$
   (b) For vertical curve sag on tangent $\Delta g_{max} = 4500/V^2$

4.2.5 Reverse Vertical Curves

Reverse vertical curves may be used if (1) the sum of the rates of change of grade per 100 ft Station of the two curves does not exceed the values defined by Section 4.2.4.2, and (2) the minimum length of each curve is not less than that defined in Section 4.2.4.1.

4.2.6 Compound Vertical Curves

Compound unsymmetrical vertical curves may be used if Δg conforms to Section 4.2.4.2 and the LVC conforms to Section 4.2.4.1.

4.3 Combined Horizontal and Vertical Curvature

Where horizontal and vertical curves are combined, the desirable rate of change of vertical grade shall be computed as follows:

$\Delta g_{max} = N/(V^2)(1-0.25U)(1-0.25E)$

where:

E and U are in inches
V = Designed speed, in mph
N = 3000 for a crest
N = 4500 for a sag

5. Trackway Horizontal Clearance

Clearances between vehicles and stationary objects shall be as follows:

All clearances shall be measured from the dynamic envelope of the outermost surface of the largest vehicle on tangent track. The spacing of tracks and structures shall be increased proportionally for curved track to provide the minimum clearances, shall be such that no contact can take place due to any condition of design wear, loading, air spring deflation, and normal lateral vehicle motion.

6. Trackwork

a. Rail Joints

Rails should be joined together with welds to provide continuous strings.

Wherever a permanent connection is made between contiguous rails of dissimilar cross section, compromise bolted joints shall be used.

The use of un-welded joints shall be minimized during design.

Joint bonds shall be installed at un-insulated bolted joints to provide a continuous path for traction power negative return current and signal circuits.

b. Rail Braces

Rail braces shall be used in special trackwork for tie and ballast open track to minimize rail batter. Rail braces shall also be used on the outside rail in non-embedded open track with an unbalanced superelevation of 3 inches or more at probable speed.

c. Insulated Joints

Insulated joints of the epoxy bonded type shall be used wherever it is necessary to electrically isolate contiguous rails from each other in order to comply with track signaling criteria.

d. Timber Crosstie Spacing

In tangent and curved track of radius greater than or equal to 300 ft, timber crossties shall be spaced 2 ft on center. In curves of radius less than 300 ft, but not less than 100 ft, timber crossties shall be spaced not more than 20 inches on center. In curves of radius less than 100 ft, timber crossties shall be spaced not more than 18 inches on center.

e. Rail Fastenings

Running rail shall be fastened to its support in each type of track construction in a manner dependent upon the type of constructions.

- Timber Crosstie Rail Fastenings: The standard rail fastening for use on timber crosstie shall be Pandrol Clips, tie plate, neoprene tie pad and screw spikes.

  Tie plates for restraining rail shall be sized and designed to support both running rail and restraining rail.

- Direct Fixation Rail Fasteners: Direct fixation rail fasteners shall be insert anchors, anchor bolts, shim pads, rail plates, rail clips and lock washers. Fasteners shall be spaced no more than 3 ft for tangent track, and curved track with radius of 300 ft or more, and 2ft for curved track with radius less than 300 ft. Spacing shall be reduced accordingly for special trackwork in accordance with AREMA Portfolio of Trackwork Plans, but not more than 2 ft.

f. Gauge Rods

Gauge rods shall be designed for attachment to the base of rail. Gauge rods shall be threaded with 2 insulated clips and 2 lock nuts at each end of the rod to provide restraint against gauge widening and narrowing.

Gauge rods shall be insulated from the rails.

Gauge rods shall be installed only in tie and ballast track on curves with a radius of less than 300 ft. Gauge rods shall be spaced approximately 6.5 ft on center. Gauge rods shall also be installed at each end of switches, frogs and crossings. Gauge rods shall not be used in direct fixation track.

g. Unreinforced Track Concrete

Unreinforced track concrete shall contain 100 percent virgin polypropylene, collated, fibrillated fibers specifically manufactured for use as concrete reinforcement, containing no reprocessed olefin materials. Fiber reinforcement shall be added to unreinforced track concrete at the rate of 0.56 lbs per cubic foot.

Control joints shall be provided in track concrete. Spacing between control joints for unreinforced concrete shall not exceed 6.5ft. Construction joints may substitute for control joints.

h. Track Drainage

Track drains shall be designed accordingly at the low points of track alignment. Track profiles and cross slopes shall be coordinated to minimize track drains.

Drain shall be installed at track switches.

i. Engineering Fabric

Engineering fabric shall be placed under track ballast and shall be manufactured from polypropylene material. The fabric shall be non-woven, shall not act as a wicking agent, shall be permeable, and shall provide separation of the ballast from other material, filtration (restrict solids from passing into the ballast while allowing more water to dissipate) and tensile reinforcement.

Fabric shall conform to AASHTO Task Force 25 requirements for high road stabilization and the following:

Elongation, percent, min. ASTM Designation D 1682	50
Puncture strength, in pounds ASTM Designation D 751 (Modified)	120
Equivalent opening size U.S. Sieve No. minimum	70

7. Special Trackwork

All special trackwork shall be located on constant profile grades without any superelevation. Crossovers shall preferably be located in parallel tracks and semi-exclusive right-of-way. All special trackwork frogs and crossings shall be fabricated from solid manganese steel castings conforming to Muni specifications for special trackwork. All single crossovers shall be trailing crossovers, composed of two right-hand turnouts.

As all special trackwork is a source of noise and vibration, due consideration shall be given to noise and vibration in their design.

8. Trackway Characteristics

Trackwork shall be designed based upon the following Trackway and Wayside, and Muni vehicle characteristics:

Trackway & Wayside Characteristics	Value
Track Gauge/Tangent & Curve R > 200 ft	4'-8½"
Track Gauge/Curve 100 ft < R ≤ 200 ft	4'-8⅝"

Track Gauge/Curve ≤ 100 ft	4'-8¾"
Flangeway Widths/Tangent & Curve R > 200 ft	1⅜"
Flangeway Widths/Curve 100 ft < R ≤ 200 ft	1½"(inside); 1⅝" (outside)
Flangeway Widths/Curve R ≤ 100 ft	1⅝" (inside); 1⅞"(outside)
Minimum Horizontal Radius (to Track Centerline)	45 ft
Minimum Desirable Horizontal Radius	50 ft
Maximum Trackway Superelevation in Shared ROW	2 in
Maximum Trackway Superelevation in Exclusive ROW	6 in
Maximum Unbalanced Superelevation	4.5 in
Minimum Vertical Crest Radius	310 ft
Minimum Vertical Sag Radius	460 ft
Absolute Minimum Vertical Curve Length	40 ft
Maximum Desirable Grade	5%
Maximum Allowable Grade	7%
Absolute Maximum Grade for a Short Distance	9%
Minimum Grade	0.3%

Clearance Requirement	Value
Centerline of Track to Edge of Platform	55⅞"+ 0"-⅛"
Height of Platform from Top of Rail	33¾"+ ¼"-0"

Breda LRV2 Vehicle Characteristics	Value
Car Length (over anti-climbers)	73 ft
Car Length (over couplers)	75 ft
Static Car Width (at threshold)	8'-8"
Static Car Width (at belt line)	9'-0"
Dynamic Car Width (at threshold)	9'-1¼"
Dynamic Car Width (at belt line)	9'-8¾"
Car Width (at mirror)	10'-2"
Floor Height (top of rail to floor)	2'-10"
Truck Wheel Base	6'-3"
Truck Centers	24 ft
Car Height (top of rail to top of roof equipment)	11'-6"
Empty Weight (exclusive of Muni equipment)	38 ton
Normal Weight (AW 1-62 passengers)	42.85 ton

Trackway & Wayside Characteristics	Value
Seated Weight (AW 2-155 passengers)	50 ton
Maximum Weight (AW 3-200 passengers)	55 ton
Weight Distribution (end trucks)	35%
Weight Distribution (center truck)	30%

9. <u>Glossary of Trackwork Terms</u>

Approach Slab (Transition Slab) - A concrete slab under ballast located at the interface of ballasted track with direct fixation track or embedded track to provide a transition between ballasted track construction and the types of track with significantly higher track modulus.

AREMA - American Railway Engineering and Maintenance-of-way Association.

At-Grade Crossing - The crossing of track across a vehicular roadway at the same elevation; conventionally constructed of asphalt and concrete.

Ballast - An integral part of the track structure, generally composed of crushed stone in which ties are embedded and essential to good maintenance of track surface and alignment. Federal Railroad Administration (FRA) Track Safety Standards stipulate that: "Unless it is otherwise structurally supported, all tracks must be supported by material that will:

a) Transmit and distribute the load of the track and railroad rolling equipment to the subgrade;
b) Restrain the track laterally, longitudinally, and vertically under dynamic loads imposed by railroad rolling equipment and thermal stress exerted by the rails;
c) Provide adequate drainage for the track; and
d) Maintain proper track cross-level, surface, and alignment.
e) Track ballast is the conventional material that performs the above functions. In addition, ballast can retard the growth of vegetation.

Rail Bond - Copper bonding cable that attached by CAD-Welding to the rail on each side of the joint to assure a path for electrical current across the joint.

Closure Rails - The standard rails placed between components of any special trackwork unit, such as the rails between the switch and the frog in a turnout.

Crossing – A structure, used where one track crosses another at grade, and consisting of four connected frogs.

Crossover, Single - Two turnouts, with track located between the turnouts and arranged to form a continuous passage between two adjacent and generally parallel tracks.

Engineering Fabric - Non woven synthetic fabric that allows water to past through but prevents the passage of fine soil materials, Engineering Fabric prevents the fouling of ballast by the migration of subgrade fines.

Flangeway - The open way through a track structure which provides a passageway for wheel flanges.

Flangeway Width - The distance between the gage line and the guard line of a track structure, which provides a passageway for wheel flanges.

Flangeway Depth – The depth of the wheel flange passageway, or the vertical distance from the top of the tread surface to the top of the filter or separator introduced between the tread portion and the guard portion of a track structure.

Frog - A track device used at the intersection of two running rails to provide support for wheel treads and flanges, thus permitting wheels traversing either rail to cross the other.

Frog Angle - The angle formed by the intersecting gage lines of a frog.

Frog Number - The number used to designate the size of a frog, and being equal to one-half the co-tangent of one half the frog angle.

Girder Rail - Any one of several types of rail sections most commonly used in electric or street railway construction. Girder groove rails are unsymmetrical rails that provide a wheel flangeway adjacent to the gauge side of the railhead. Girder guard rails utilize a similar flangeway but with a raised lip to provide a guarding action similar to that provided by a separate restraining rail.

Guard Rail - A rail installed parallel to and inside of the running rails of a track to hold wheels in correct alignment to prevent their flanges from striking the points of turnout or crossing frogs or the points of switches. The term is sometimes applied to other track more properly referred to as restraining rail or emergency guard rail.

Guard Rail, Emergency - A rail or other structure installed parallel to and approximately one foot inside of the running rails of track to keep the wheels of a derailed vehicle reasonably adjacent to the running rails and following the general alignment of the track.

Gauge Rod - A steel bar or rod that clamps to the rail bases of the running rails and to hold the rails to proper track gauge. Gauge rod is used in turnouts and curves to maintain accurate gauge.

Inside Rail - On a curved track, the rail closer to the curve center; the rail with the shorter radius. On a curved track that is superelevated, it is sometimes referred to as the "low rail."

Joint Bar - Device used to join the abutting ends of contiguous unwelded rails.

Joint Bar, Compromise - A joint bar used to connect contiguous unwelded rails of different cross sections.

Joint Bar, Glued - Joint bar shaped with maximum surface-to-rail contact for adhesion to rail with epoxy adhesive.

Joint Bar, Insulated - An assembly of two special joint bars, track bolts, insulating sleeves, and insulated end post. The special joint bars are designed to stiffen the joint and prevent the passage of rail current across the joint.

Outside Rail - On a curved track, the rail further from the curve center; the rail with the longer radius. On a curved track which is superelevated, it is sometimes referred to as the "high rail."

Profile Grade Line (PGL) - The datum line which defines the vertical alignment of the track, and represents the average of the two rails.

Rail Brace - A bracing device used in combination with a switch or at other locations where rail is subject to batter.

Rail Fastener - A device used to secure running rails to ties in ballasted track, to a concrete trackbed in direct fixation track or to embedded track at the proper track gauge and to provide proper vertical, lateral and longitudinal restraint of the rail.

Rail, Compromise - A relatively short rail the two ends of which are of different sections, corresponding with the sections of the rails to which they are to be joined; it provides the transition from one section to a different rail section.

Rail, Tee - The common class of steel rail for track construction which is symmetrical in section and resembles an inverted letter "T". The term "standard" is commonly associated with tee rail sections.

Rail, Premium - Rail which has a Brinell hardness between 321 and 388 which is achieved by fully heat treating, or alloy composition.

Restraining Rail - A rail installed adjacent to and parallel with the running rail of curved track. It bears against at the back side of the wheels and steers the wheels of each truck around the curve, thereby preventing the wheel flange from climbing the rail. It also reduces gauge side wear on the running rail.

Special Trackwork - A generic term referring to turnouts, single and double crossovers, track crossings, and other such items.

Stock Rail - A running rail against which a switch rail operates in a turnout.

Subgrade - The finished surface of the roadbed below ballast or track slab.

Switch, Mate - A track structure having a fixed or immovable point and used on the opposite side of the track from a tongue switch, as its companion piece. (A mate is termed "outside" or "inside" depending upon whether it is placed on the outside or inside of the curve, the "inside mate" being comparatively little used.)

Switch, Tongue - A switch deflecting device consisting essentially of a movable tongue within suitable enclosing and supporting body structures. Used in a turnout in embedded track. Often used in conjunction with a non-moving deflection device called a mate.

Switch, Point of - The tip of the tapered end of a switch rail; end of a switch rail farthest from the frog or heel block.

Switch Rail (Switch Point) - The tapered rail of a split switch.

Top of Rail (T/R) - That portion of the running rail that follows the PGL; the top surface of the head of the running rail.

Track, Ballasted - Track constructed of rail and crossties on ballast.

Track, Direct Fixation - Track constructed of rail and rail fasteners attached by means of anchor bolts to a reinforced concrete track slab.

Track, Embedded - Track that is embedded in asphalt, concrete, or other such material to the elevation of the top of rail to facilitate pedestrian or vehicular traffic over the track.

Track Gauge - The distance measured between and perpendicular to the track gauge lines.

Track Gauge Line - A line 5/8 inch below the top of the center line of the head of the running rail or corresponding location of tread portion of other track structures along that side which is nearer the center of the track.

Track Slab - The reinforced concrete foundation that supports the track itself, generally in conjunction with direct fixation track.

Turnout - An arrangement of a switch and a frog with stock rails and closure rails, enabling rail vehicles to be diverted from one track to another.

Turnout, Lateral - A turnout in which the diversion due to the angle of the turnout, is entirely in one direction away from track from which the turnout is made.

12.2 Overhead

A. Overhead Contact System for LRV/PCC

Overhead hardware used should be products of manufacturers regularly engaged in the production of such material and equipment, and is of the manufacturer's latest design approved by Muni. This is to ensure compatibility and interchangeability with the current Muni overhead hardware and spare parts. The followings are specific hardware characteristics for the project:

1. Hardware Criteria

1.1 **Overhead Contact System Type** – Single wire direct suspension.

1.2 **Contact Wire** – Contact wire shall be bronze, grooved, alloy 80 conforming to ASTM B9-90. The following characteristics will be used:

Description	Muni Standards
Contact Wire for LRV/PCC	#4/0
#4/0 Contact Wire Tension @ 60°F	3750 lb per wire

Contact Wire Height at Surface	18.50 ft ± 0.26 ft
Maximum Unsupported Contact Wire Span	100 ft

1.3 **Frogs** – Leading and trailing frogs for PCC/ LRV will be 10° shallow grooved solid body type. The leading PCC/ LRV switch will be positioned to allow for optimal performance of LRV operation.

2. Contact Wire Alignment

2.1 **For Special Trackwork** – At track curves, crossovers and turnouts, OCS will be designed to maintain continuity of contact between the contact wire and the LRV pantograph. The contact wire will be offset from the track centerline to within the zones as shown on Standard Drawing K-41, "Transit Power Facilities" – Location of Contact Wire Above Track for Pole and Pantograph Operation" dated September 1978. Each track curve, crossover and turnout will require evaluation of the following parameters to determine the required contact wire offset.

- Minimum curve radius
- Radius of spiral curve entering
- Radius of spiral curve exiting
- Curve superelevation

2.2 **For Tangent Trackage** – At tangent trackage, the contact wire will be staggered from track centerline to allow uniform wearing of pantograph carbon collector strip. Staggers will be as shown on Muni Standard Drawing A-1530, Rev. 0, "Transit Power Facilities – Streetcar Overhead System – Stagger Diagram" dated August 1979.

B. Overhead Contact System for Trolley Coaches

Overhead hardware used should be products of manufacturers regularly engaged in the production of such material and equipment, and is of the manufacturer's latest design approved by Muni. This is to ensure compatibility and interchangeability with the current Muni overhead hardware and spare parts. The followings are specific hardware characteristics for the project:

1. Hardware Criteria

1.1 **Overhead Contact System Type** – OCS shall be a rigid type system similar to Ohio Brass (OB) / Westinghouse Air Brake Company (WABCO) / Impulse N, Inc Contact System or a flexible system similar to Kummler & Matter System.

1.2 **Contact Wire** – Contact wire shall be bronze, grooved, alloy 80 conforming to ASTM B9-90. The following characteristics will be used:

Description	Muni Standards
Contact Wire for Trolley Vehicles	#2/O
#2/O Contact Wire Tension @ 60°F	2000 lb per wire
Contact Wire Height	19 ft ± 3 in
Contact Wire Spacing	2 ft
Axis of Trolleywire pair from curb unless otherwise noted	14 ft
Maximum Unsupported Contact Wire Span	100 ft

1.3 **Overhead Components and Trolley Wire Replacement** – Replace overhead components and trolley wires that have a service life of less than 50%.

1.4 **Leading Switch** – 15 ° Induction Controlled.

2. **Trolley Wire Alignment** in accordance with guidelines and criteria established by Municipal Railway High Performance Trolley Coach Overhead Minimum Standards.

C. Overhead Supports and Foundations

1. OCS Poles

Steel poles will be in accordance with Muni Standard Drawing CL-7971, Rev. 2. For all Standard applications, pole Types 761N, 765N, 767 and 770 shall be used.

New poles will be in line with property line between adjacent properties and avoid fronting doors, windows, and access ways wherever possible. Where an existing pole is replaced with a new pole, the new pole will be at approximately 4 ft away from the present location. At intersections adjoining side platforms the poles should be as clear of the corner as possible to avoid being hit by right turning trucks.

Wherever possible, poles will be combined with streetlight and traffic signals to reduce the number of poles. Poles with feeder risers inside will not be combined with traffic signals.

2. Pole Foundations

Existing foundations will be removed to a depth of 3 ft below the finished grade. Where a pole has to be replaced in place due to space constraint, the existing foundation will be removed entirely and new foundation installed in place.

New standard pole foundations will be in accordance with Muni Standard Drawing CL-7971, Rev. 2. Where special foundations are required, they will be designed according to the current codes and regulations.

3. **Pole Replacement**

Replace City owned wood poles, concrete poles, and steel poles that are bending, leaning, deeply pitted, or with rust and/or holes along the shaft or base.

4. **Protection Devices**

Wood troughs, preformed glass/epoxy shields, or approved apparatus of a custom design if necessary, will be used wherever the overhead support structure shall be protected against possible arcing conditions.

Guy wire span supports shall include tree guard or similar item to protect against trolley shoe snags during dewirement from a trolley vehicle.

5. **Finish Treatment**

Unless otherwise required by urban design requirements or streetscape master plan, new steel pole shall have a galvanized finish (Not Painted). Existing steel trolley pole shall be painted to match galvanizing or existing coating color. Anti-graffiti coating shall be applied to the bottom 8' of the pole.

6. **All OCS poles should be grounded.**

D. Design Codes and Guidelines

- California Public Utilities Commission (CPUC) General Order No. 95, Rules for Overhead Line Construction
- California Public Utilities Commission (CPUC) General Order No. 128, Rules for Construction of Underground Electric Supply and Communications Systems.
- Muni High Performance Trolley Coach Overhead Wire Minimum Standards
- California Code of Regulation (CCR), Title 8; Industrial Relation

12.3 Electrical

A. Track Switch and Signal Interlocking System

All track switches will be electrically controlled and shall be operated by track switch operators. Aspect signals to indicate the position of each track switch shall be provided. Interlocking of track switches and signals shall be incorporated into track switch control system.

1. Track Switch Operators

   The track Switch operators for the track switches signal shall be solenoid type with position indications for single tongue and mate trailable track switches.

2. Track Switch Controller

   Track switch controller shall be designed by utilizing conventional relay circuitry and Vital Programmable Logic Controller (VPLC) circuitry to provide the logic and interlocking functions for the control and signaling of all track switches. Major components of the track switch control such as relays, power supply and transformer, VPLC, Local Control Panel, shall be housed in the wayside cabinet. 120/240 VAC single phase 60 hertz utility shall be provided to track switch control and operation system.

3. LRV Train Signals.

   8-inch four aspect LED type LRV signal shall be provided for each track switch. The stacking of the LRV signal heads, from top to bottom, shall be as follows: lunar white (confirm), vertical bar (Straight), diagonal left or right (diverge) and red cross-buck (stop).

4. Track Circuits

   Each track switches shall have "Protective Track Circuit"(BT), which encompasses the switch itself. This track circuit prevents the track switch from moving when a train is occupying this circuit.

   An "Approach Track Circuit" (AT) shall be provided at each track switch for initiating route request for the Normal route.

   Insulated joints (IJs) shall be installed in strategic locations to electrically isolate rails in order to meet track switch signal interlocking requirements.

5. Routing Requests

Combined Approach Track circuit and Vehicle Tagging System (VETAG) shall be used for initiating routing requests for Normal moves. VETAG shall be used to set route requests for Reverse moves.

B. Streetlights

The streetlight luminaries and bracket arm shall be decorative tear drop type, high pressure sodium vapor lamps with operating voltage of 120/240 VAC. The streetlights shall meet the minimum standards that are recommended by the Illuminating Engineering Society (IES) for street lighting. The streetlights illumination level should be from 0.4 to 0.8 average foot-candles and the illumination uniformity ratio shall be 3:1 for average to minimum foot-candles and 5:1 for maximum to minimum foot-candles.

12.4 Civil

Refuge Area: A minimum personnel refuge area measuring 30" high and 30" deep shall be provided under high level platform.

Platform Height: The height is measured from the top-of –rail.

Platform Clearance from Train: The clearance between the boarding edge-of-platform is measured from the centerline of track. The clearance shall accommodate both moving and parked train. The clearance shall be adequate even when the train opens its doors.

Ramp Grade: The maximum grade of the ramp is 8.33 percent and its length shall not exceed 30 feet. The landing area length shall be five feet minimum. If longer, an intermediate landing area is required.

Ramp Width: The minimum clear width of the ramp shall be three feet. This width shall match landing area width.

Hand Railing:

- Handrail shall be provided along both sides of ramp and shall be continuous.
- The minimum handrail gripping surface shall be 34 inches above ramp floor and at least 1 ½ inches from any other surface.
- The required handrail thickness is 1 ¼ inches.
- Handrail shall extend at least 12 inches beyond the top and bottom of the ramp segment.
- The handrail frames shall resist at least lateral force of 200 lbs.

12.5 Roadway Pavement

Unless noted otherwise, new road pavement outside of track right of way or alteration to existing road pavement shall be designed to match the existing.

2. LRV Dynamic Envelope

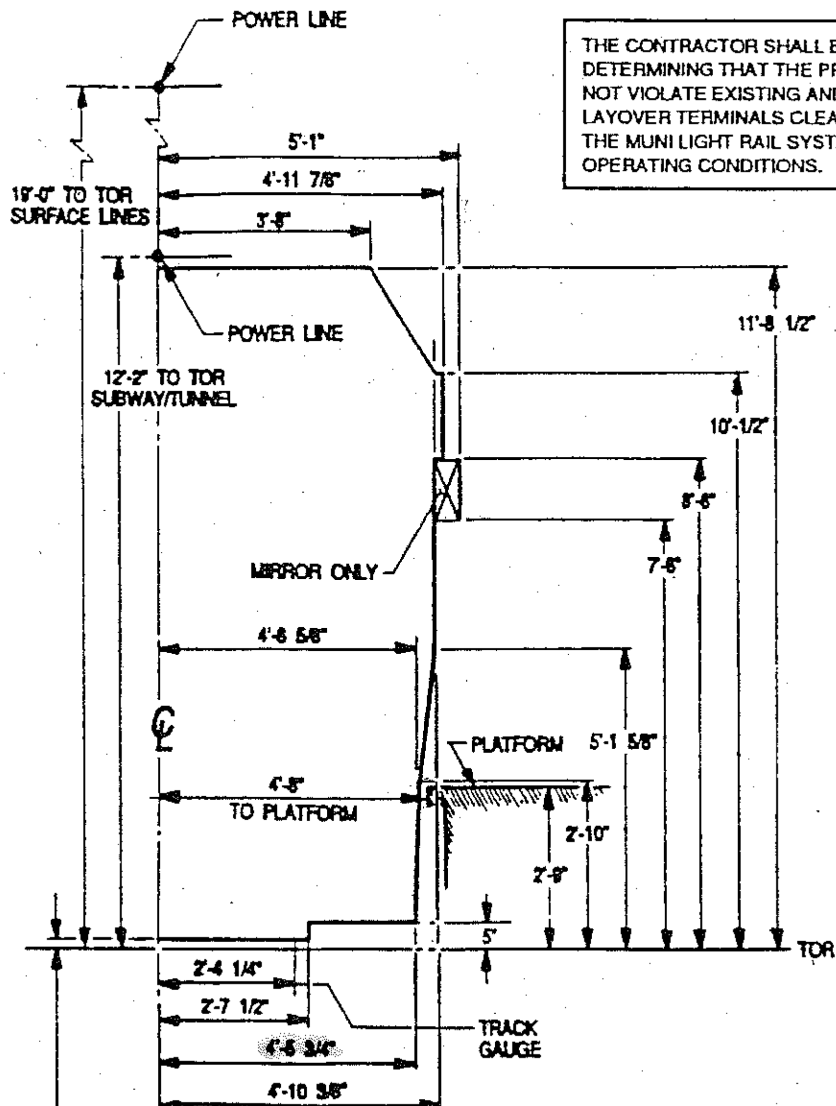
appendix **forty-five**

LRV Dynamic Envelope

for reference only

EXHIBIT 2-3

LRV2 DYNAMIC OUTLINE



THE CONTRACTOR SHALL BE RESPONSIBLE FOR DETERMINING THAT THE PROPOSED LRV SHALL NOT VIOLATE EXISTING AND NEW EXTENSIONS AND LAYOVER TERMINALS CLEARANCE ENVELOPS ON THE MUNI LIGHT RAIL SYSTEM UNDER NORMAL OPERATING CONDITIONS.

MINIMUM CLEARANCE AFTER ALL WEAR AND DEFLECTION, OVER MIN R VERTICAL CURVE
-2" UNDER TRUCK AND UNDER CAR COMPONENTS
-4" UNDER CAR EQUIPMENT OUTSIDE THE TRUCKS

NOTES:

1. THE DYNAMIC OUTLINE REPRESENTS THE MAXIMUM ALLOWED EXCURSION WITH THE DOOR CLOSED, NEW WHEELS ON NEW TANGENT TRACK.
2. THE DYNAMIC OUTLINE INCLUDES:
   (a.) LATERAL DISPLACEMENT OF PRIMARY AND SECONDARY SUSPENSION
   (b.) CAR BODY ROLL
   (c.) MANUFACTURING TOLERANCES
3. THE DYNAMIC OUTLINE DOES NOT INCLUDE:
   (a.) TRACK TOLERANCES AND WEAR
   (b.) WHEEL FLANGE WEAR
   (c.) SUPERELEVATION

CASE (I):

CLEARANCE ON BOARDING ISLANDS, IN YARDS AND ALONG SHOP AISLES, EMERGENCY WALKWAYS WHERE PASSENGERS, EMPLOYEES AND OTHER PERSONS ARE PERMITTED OR REQUIRED TO BE WHILE TRAINS ARE IN MOTION. (REF. 1.,SEC. 9.06c(1)).

A. MINIMUM SIDE CLEARANCE FROM VEHICLE TO OBSTRUCTIONS HIGHER THAN 203mm [8 INCHES] ABOVE TOP OF RAIL (T/R).

NOTES:

1. ALL CLEARANCES ARE TO BE MEASURED FROM THE DYNAMIC ENVELOPE OF THE OUTERMOST SURFACE OF THE LARGEST VEHICLE TO THE NEAREST POINT OF STRUCTURE.
2. ALL CLEARANCE CONDITIONS SHALL APPLY TO LIGHT RAIL VEHICLES AND STREETCARS OPERATED IN BOTH TANGENT AND CURVED TRACKS FOR NEW LIGHT RAIL TRANSIT AND TRACK REPLACEMENT PROJECTS.
3. CLEARANCE LESS THAN 762mm [30"] MAY BE FILED TO CALIFORNIA STATE PUBLIC UTILITIES COMMISSION FOR REVIEW / APPROVAL IF PROJECT DESIGN CAN DEMONSTRATE THAT:
   1. THE STRUCTURE (E.G CANOPY ROOF, LIGHTING ARM, SIGNAL PANEL) IS INACCESSIBLE TO PASSENGERS AND
   2. TRAIN OPERATION CONTROL IS PROVIDED AND MONITORED WHILE THE MAINTENANCE / REPAIR WORK OF THE STRUCTURE IS UNDERTAKING.

REFERENCE:

1. CALIFORNIA STATE PUBLIC UTILITIES COMMISSION GENERAL ORDER 143-B; JANUARY 20, 2000
2. CONTRACT PROPOSAL #309, PROCUREMENT OF LIGHT RAIL VEHICLES, SAN FRANCISCO MUNICIPAL RAILWAY, JANUARY 6, 1992.

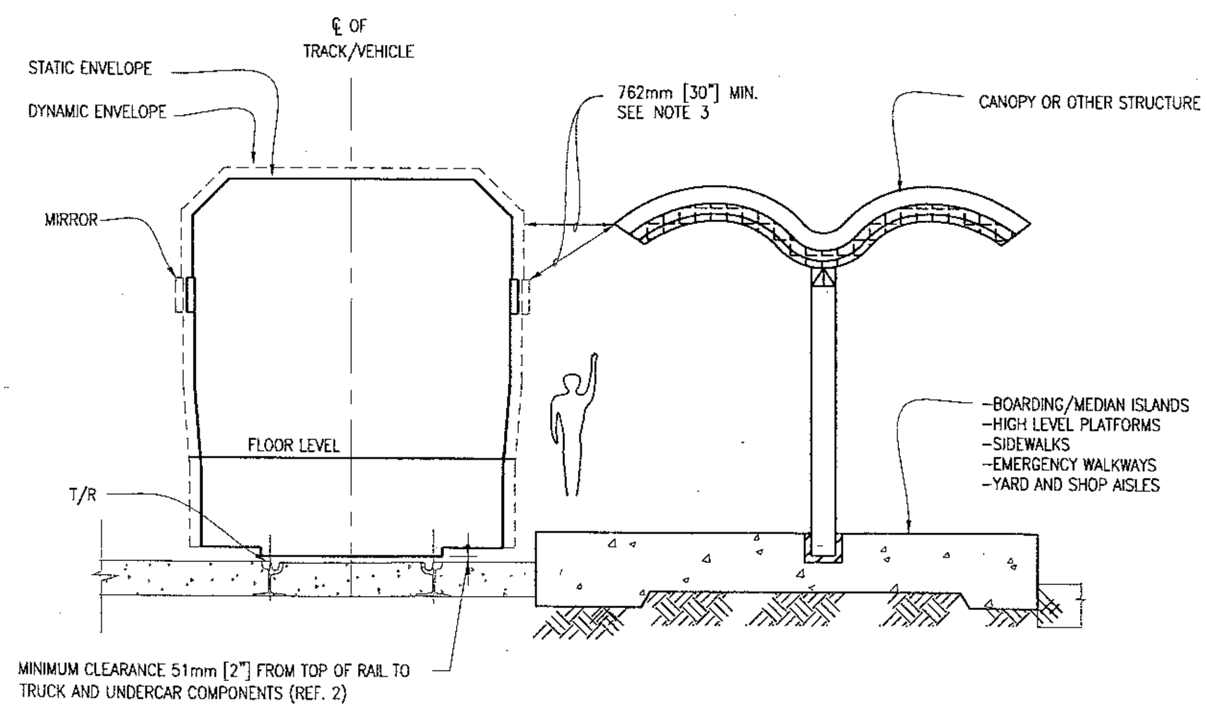


FIGURE I

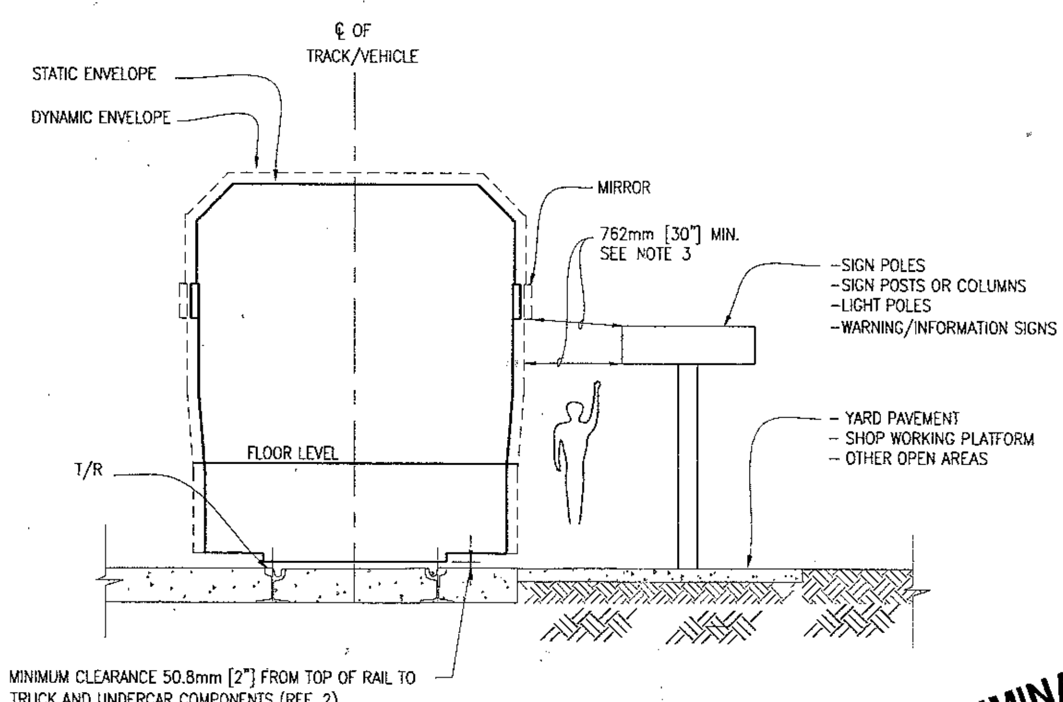


FIGURE II

PRELIMINARY DRAWING
SUBJECT TO CHANGE

NO.	DATE	DESCRIPTION	REVISED	CHECKED	APPROVED

REVISIONS

DESIGNED
DRAWN
CHECKED
REVIEWED
RECOMMENDED
APPROVED
DATE

SEAL OF THE CITY AND COUNTY OF SAN FRANCISCO

CITY AND COUNTY OF SAN FRANCISCO
MUNICIPAL RAILWAY

APPROVED

GENERAL MANAGER

LIGHT RAIL TRANSIT SYSTEM

VEHICLE CLEARANCES CASE (I)

CONTRACT MR-XXXX
DRAWING TR/CLR-01
REVISION 0
NTS

PROJ. NO./FILENAME : T:\TRACK STD\CRV CLEARANCE\TR_CLR-01

CASE (II):

CLEARANCES AT LOCATIONS AND IN AREAS WHERE PASSENGERS, EMPLOYEES AND OTHER PERSONS ARE NORMALLY PROHIBITED WHILE TRAINS ARE IN MOTION. (REF. 1., SEC. 9.06c(2).)

A. MINIMUM CLEARANCE BETWEEN VEHICLES AND MINIMUM TRACK SPACING BETWEEN PARALLEL TRACKS.

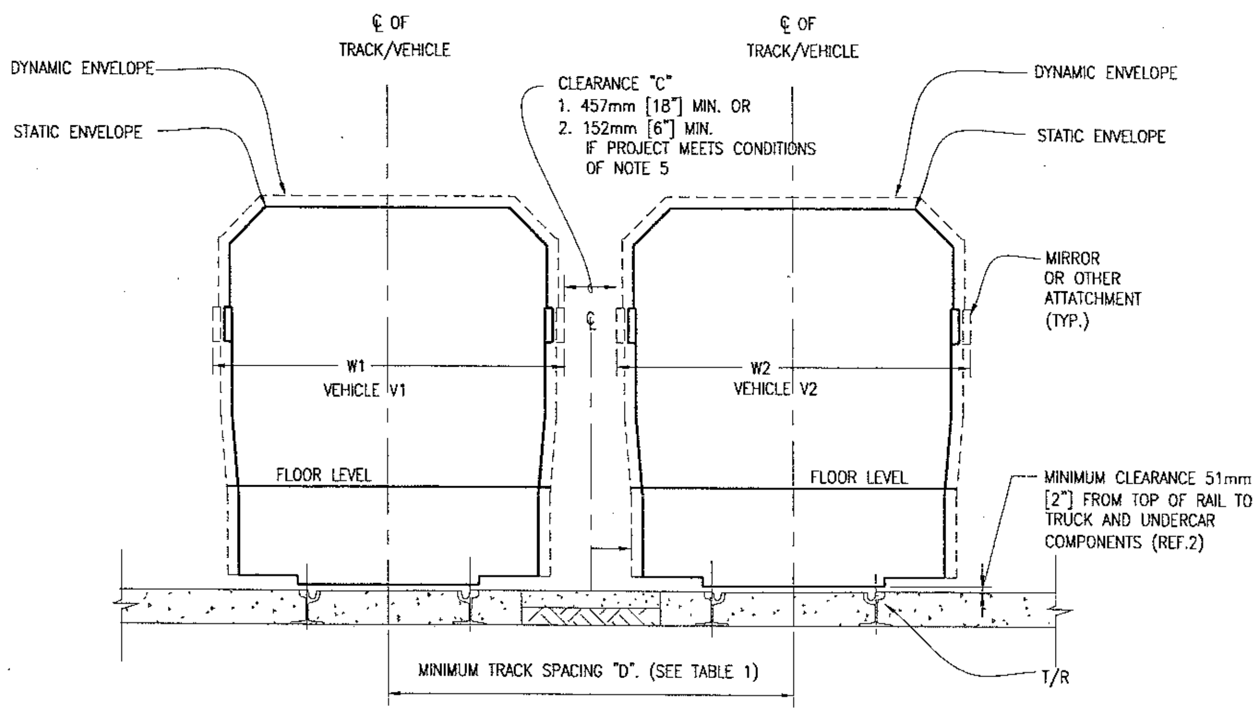


FIGURE I:

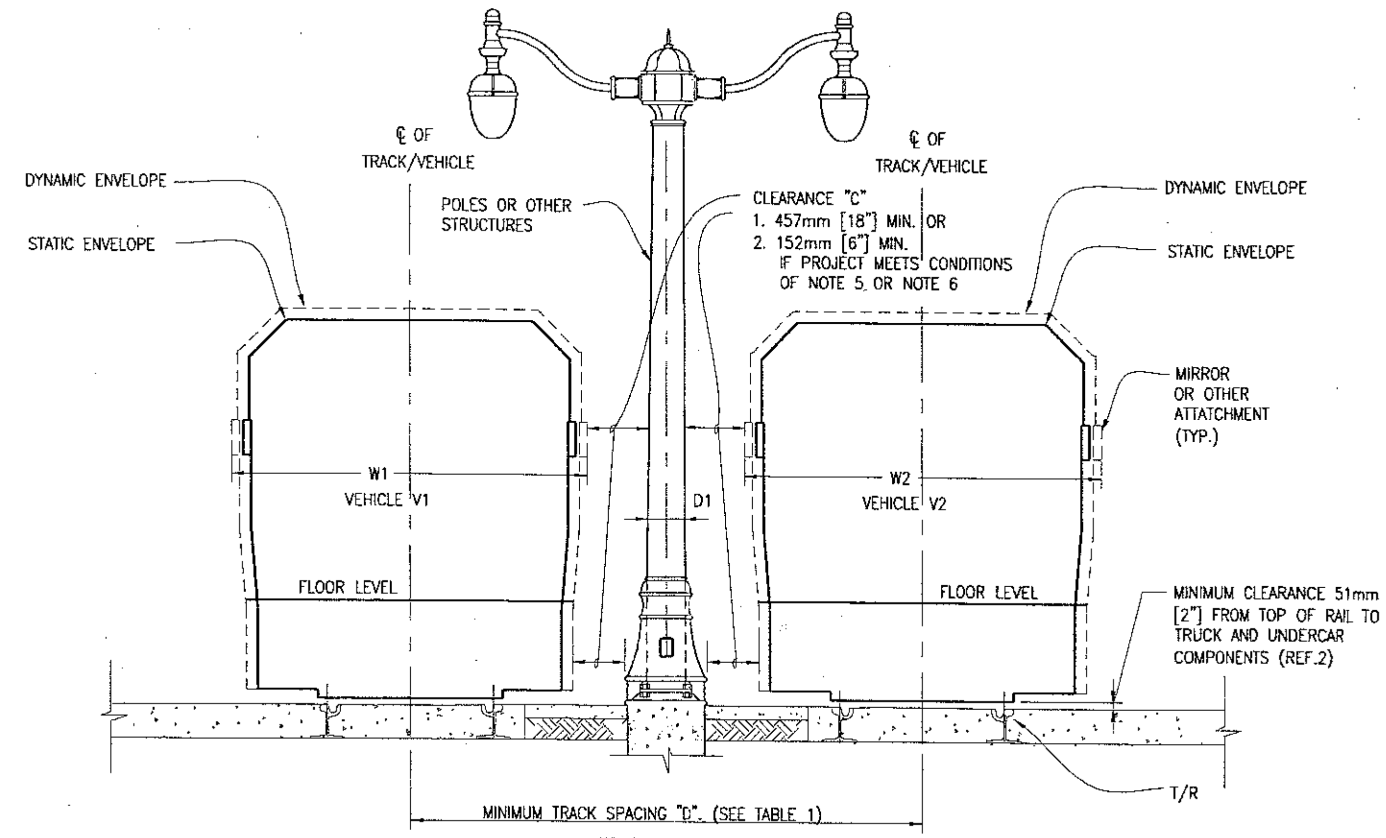


FIGURE II:

TABLE 1. MINIMUM SPACING BETWEEN TANGENT TRACKS (SEE NOTE 4)

OPERATION		W1 m [FT]	W2 m [FT]	* MINIMUM TRACK SPACING "D" m [FT]					
				FIGURE I		FIGURE II			
						457mm [18"] CLEARANCE "C"		152mm [6"] CLEARANCE "C"	
VEHICLE V1	VEHICLE V2			457mm [18"] CLEARANCE "C"	152mm [6"] CLEARANCE "C"	D1=305mm [12"]	D1=457mm [18"]	D1=305mm [12"]	D1=457mm [18"]
LRV2	LRV2	3.100m [10.17']	3.100m [10.17']	3.557m [11.67']	3.252m [10.67']	4.319m [14.17']	4.471m [14.67']	3.709m [12.17']	3.862m [12.67']
LRV2	PCC	3.100m [10.17']	3.048m [10.00']	3.531m [11.59']	3.228m [10.59']	4.293m [14.09']	4.446m [14.59']	3.685m [12.09']	3.837m [12.59']
LRV2	LRV1	3.100m [10.17']	2.990m [9.81']	3.502m [11.49']	3.197m [10.49']	4.264m [13.99']	4.417m [14.49']	3.655m [11.99']	3.807m [12.49']
LRV1	LRV1	2.990m [9.81']	2.990m [9.81']	3.447m [11.31']	3.142m [10.31']	4.209m [13.81']	4.362m [14.31']	3.600m [11.81']	3.752m [12.31']
LRV1	PCC	2.990m [9.81']	3.048m [10.00']	3.476m [11.41']	3.478m [11.41']	4.238m [13.91']	4.392m [14.41']	3.630m [11.91']	3.783m [12.41']
PCC	PCC	3.048m [10.00']	3.048m [10.00']	3.505m [11.50']	3.505m [11.50']	4.267m [14.00']	4.420m [14.50']	3.658m [12.00']	3.810m [12.50']

W1,W2 = MAXIMUM WIDTH OF LARGEST VEHICLE DYNAMIC ENVELOPE (IN METERS)
D (FIG. I) = [(W1+W2)/2+("C"/1000)]m
D (FIG. II) = [(W1+W2)/2+[("C"+"C"+D1)/1000]]m
"C" = MINIMUM ALLOWABLE CLEARANCE (IN MILLIMETERS)
D1 = POLE DIAMETER OR LARGEST SIDE DIMENSION OF STRUCTURE; FOR TAPER-SECTION POLE, USE LARGEST DIAMETER AT BASE.
LRV2 = BREDA LIGHT RAIL VEHICLE
LRV1 = BOEING VERTOL LIGHT RAIL VEHICLE
PCC = PRESIDENT'S CONFERENCE COMMITTEE VEHICLE (USE 3.048m [10.00'] WIDTH OF "THE TORPEDOES" IN CALCULATION)
*TRACK SPACING SHALL BE ADJUSTED ACCORDINGLY TO ALLOW HISTORIC STREETCAR OPERATION (3.200m [10'-6"] WIDTH OF VEHICLE # 130 MAY BE USED FOR ADJUSTMENT).

NOTES:

1. ALL CLEARANCES ARE TO BE MEASURED FROM THE DYNAMIC ENVELOPE OF THE OUTERMOST SURFACE INCLUDING ATTACHMENTS OF THE LARGEST VEHICLE.
2. ALL CLEARANCE CONDITIONS SHALL APPLY TO LIGHT RAIL VEHICLES AND STREETCARS OPERATED ON BOTH TANGENT AND CURVED TRACKS FOR NEW LIGHT RAIL TRANSIT AND TRACK REPLACEMENT PROJECTS.
3. THE TRACK SPACING SHOWN IN TABLE 1 APPLIES TO VEHICLES ON TANGENT TRACKS ONLY.
4. FOR CURVED TRACKS, MINIMUM TRACK SPACING SHOULD BE INCREASED AND DESIGNED ACCORDINGLY BASED ON THE MOST CRITICAL VEHICLE DYNAMIC ENVELOPE INCLUDING ITS ATTACHMENTS (E.G. MIRRORS, ETC.), TRACK GEOMETRY, AND SUPERELEVATION.
5. IN EXCLUSIVE RIGHT-OF-WAYS INCLUDING SUBWAYS, TUNNELS, AND PORTIONS OF SURFACE AND ELEVATED ALIGNMENT WHICH ARE EQUALLY INACCESSIBLE TO PERSONS, CLEARANCES MAY BE REDUCED TO THE DYNAMIC ENVELOPE OF THE LARGEST RAIL VEHICLE OPERATED, PROVIDED ALL LRVS AND STREETCARS MEET THE FOLLOWING CONDITIONS (REF.1,SEC.9.06C. (3)):
ALL WINDOWS, EXCEPT THOSE ENTIRELY WITHIN OPERATOR'S CAB, SHALL BE DESIGNED AND CONSTRUCTED SO AS TO DETER A PERSON'S HEAD OR ARM FROM BEING READILY EXTENDED TO THE OUTSIDE FROM AN OPEN WINDOW.
6. FIXED WAYSIDE STRUCTURES LESS THAN 1.524m [5'] IN LENGTH (e.g. CATENARY AND SIGNAL POLES, SWITCHING EQUIPTMENT) SHALL BE EXCLUDED FROM 457mm [18"] CLEARANCE REQUIREMENT, PROVIDED APPROVED MEASURES ARE TAKEN TO GIVE WARNING OF RESTRICTED CLEARANCES. INSTEAD, 152mm [6"] CLEARANCE SHALL BE USED FOR DESIGN.

REFERENCE:

1. CALIFORNIA STATE PUBLIC UTILITIES COMMISSION GENERAL ORDER 143-B; JANUARY 20, 2000
2. CONTRACT PROPOSAL #309, PROCUREMENT OF LIGHT RAIL VEHICLES, SAN FRANCISCO MUNICIPAL RAILWAY, JANUARY 6,1992

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DATE

SEAL OF THE CITY AND COUNTY OF SAN FRANCISCO

CITY AND COUNTY OF SAN FRANCISCO
MUNICIPAL RAILWAY
APPROVED
GENERAL MANAGER

LIGHT RAIL TRANSIT SYSTEM
VEHICLE CLEARANCE CASE (II)

CONTRACT MR-XXXX
DRAWING TR/CLR-03
REVISION 0
NTS

PROJ. NO./FILENAME : F:\TRACK STD\LRV CLEARANCE\TR_CLR-03

CASE (I) CONT:

CLEARANCES ON BOARDING ISLANDS, IN YARDS AND ALONG SHOP AISLES, EMERGENCY WALKWAYS WHERE PASSENGERS, EMPLOYEES AND OTHER PERSONS ARE PERMITTED OR REQUIRED TO BE WHILE TRAINS ARE IN MOTION. (REF. 1., SEC. 9.06c(1))

B. MINIMUM CLEARANCE BETWEEN VEHICLES AND MINIMUM TRACK SPACING BETWEEN PARALLEL TRACKS.

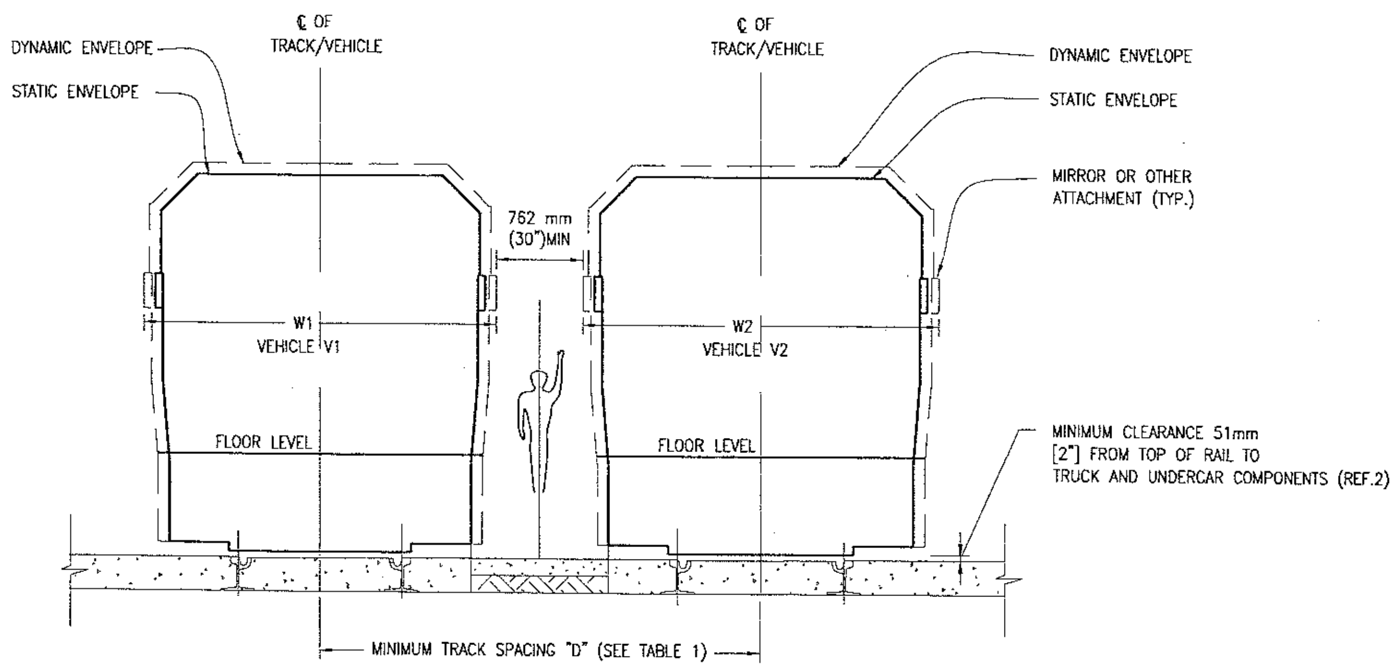

FIGURE I

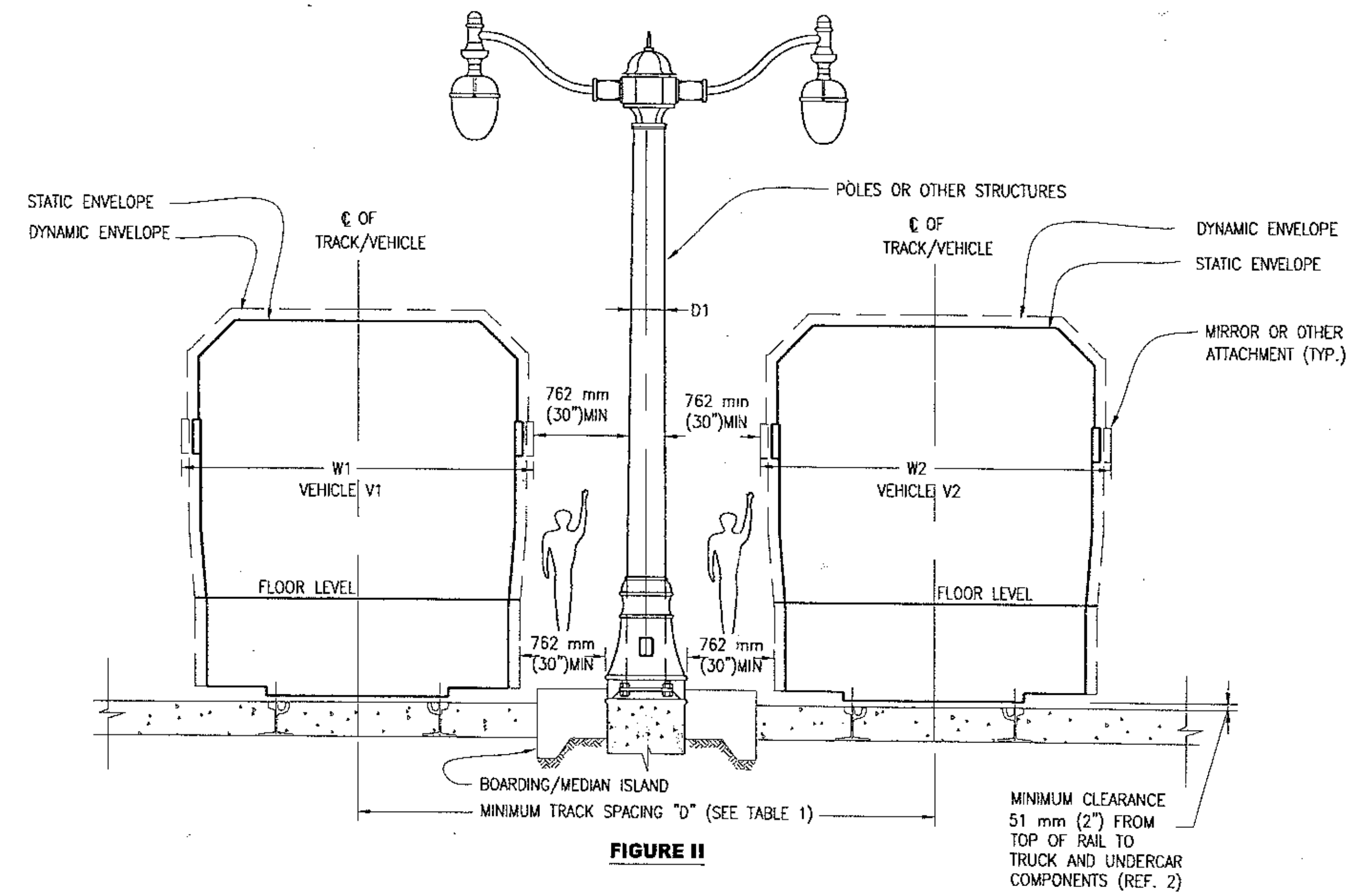

FIGURE II

TABLE 1. MINIMUM SPACING BETWEEN TANGENT TRACKS (SEE NOTE 4)

OPERATION		W1 m[FT]	W2 m[FT]	* MINIMUM TRACK SPACING "D" m [FT]			
VEHICLE V1	VEHICLE V2			FIGURE I	FIGURE II		
					D1=305mm [12"]	D1=457mm [18"]	D1=508mm [20"]
LRV2	LRV2	3.100m [10.17']	3.100m [10.17']	3.862m [12.67']	4.929m [16.17']	5.081m [16.67']	5.133m [16.84']
LRV2	PCC	3.100m [10.17']	3.048m [10.00']	3.836m [12.59']	4.903m [16.09']	5.055m [16.59']	5.105m [16.75']
LRV2	LRV1	3.100m [10.17']	2.990m [9.81']	3.807m [12.49']	4.874m [15.99']	5.026m [16.49']	5.078m [16.66']
LRV1	LRV1	2.990m [9.81']	2.990m [9.81']	3.752m [12.31']	4.819m [15.81']	4.971m [16.31']	5.023m [16.48']
LRV1	PCC	2.990m [9.81']	3.048m [10.00']	3.781m [12.41']	4.848m [15.91']	5.000m [16.41']	5.051m [16.57']
PCC	PCC	3.048m [10.00']	3.048m [10.00']	3.810m [12.50']	4.876m [16.00']	5.029m [16.50']	5.081m [16.67']

W1,W2 = MAXIMUM WIDTH OF LARGEST VEHICLE DYNAMIC ENVELOPE (IN METERS)
D (FIG. I) = [(W1+W2)/2+(762mm/1000)]m
D (FIG. II) = [(W1+W2)/2+[(762mm+762mm+D1)/1000]]m
D1=POLE DIAMETER OR LARGEST SIDE DIMENSION OF STRUCTURE; FOR TAPER-SECTION POLE, USE LARGEST DIAMETER AT BASE.
LRV2= BREDA LIGHT RAIL VEHICLE
LRV1= BOEING VERTOL LIGHT RAIL VEHICLE
PCC= PRESIDENT'S CONFERENCE COMMITTEE VEHICLE (USE 3.048m [10.00'] WIDTH OF "THE TORPEDOES" IN CALCULATION)
* TRACK SPACING SHALL BE ADJUSTED ACCORDINGLY TO ALLOW HISTORIC STREETCAR OPERATION (3.200m [10'-6"] WIDTH OF VEHICLE # 130 MAY BE USED FOR ADJUSTMENT).

NOTES:

1. ALL CLEARANCES ARE TO BE MEASURED FROM THE DYNAMIC ENVELOPE OF THE OUTERMOST SURFACE OF THE LARGEST VEHICLE TO THE NEAREST POINT OF STRUCTURE.
2. ALL CLEARANCE CONDITIONS SHALL APPLY TO LIGHT RAIL VEHICLES AND STREETCARS OPERATED ON BOTH TANGENT AND CURVED TRACKS FOR NEW LIGHT RAIL TRANSIT AND TRACK REPLACEMENT PROJECTS.
3. THE TRACK SPACING SHOWN IN TABLE 1 APPLIES TO VEHICLES ON TANGENT TRACKS ONLY.
4. FOR CURVED TRACKS, MINIMUM TRACK SPACING SHOULD BE INCREASED AND DESIGNED ACCORDINGLY BASED ON THE MOST CRITICAL VEHICLE DYNAMIC ENVELOPE INCLUDING ITS ATTACHMENTS (E.G. MIRRORS, ETC.), TRACK GEOMETRY, AND SUPERELEVATION.

REFERENCE:

1. CALIFORNIA STATE PUBLIC UTILITIES COMMISSION GENERAL ORDER 143-B; JANUARY 20, 2000
2. CONTRACT PROPOSAL #309, PROCUREMENT OF LIGHT RAIL VEHICLES, SAN FRANCISCO MUNICIPAL RAILWAY, JANUARY 6, 1992.

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DATE

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MUNICIPAL RAILWAY
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GENERAL MANAGER

LIGHT RAIL TRANSIT SYSTEM

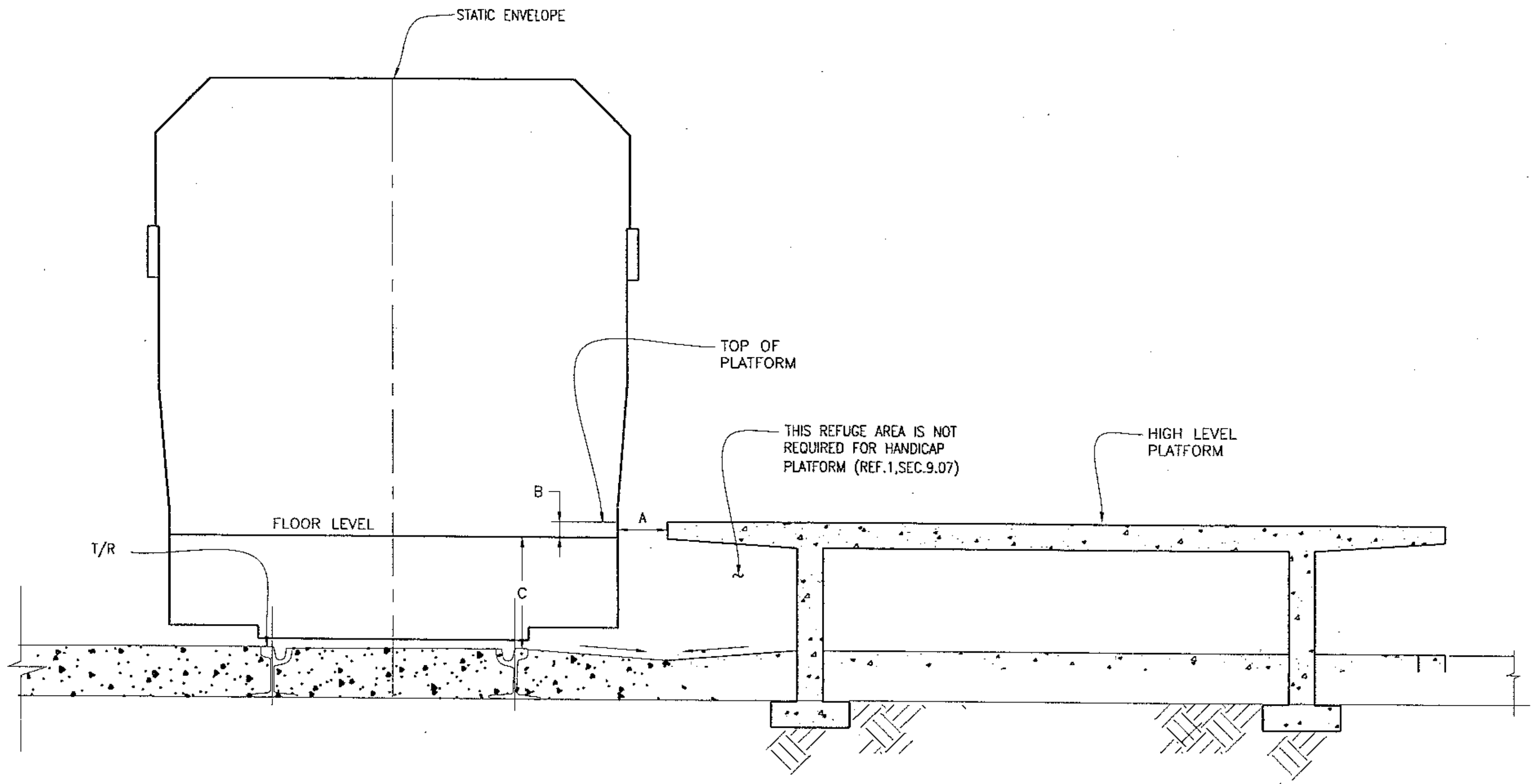
VEHICLE CLEARANCE CASE (I) CONTINUED

CONTRACT MR-XXXX
DRAWING TR/CLR-02
REVISION 0
NTS

PROJ. NO./FILENAME : F:\TRACK STD\LRV CLEARANCE\TR_CLR-02

CASE (III):

CLEARANCES ON HIGH LEVEL BOARDING PLATFORM WHILE TRAINS ARE AT REST.
(REF. 1, SEC. 9.07)



NOTES:

1. ALL DIMENSIONS ARE TO BE MEASURED WHEN TRAINS ARE AT REST
2. "A" IS HORIZONTAL GAP BETWEEN VEHICLE DOORSILL AND PLATFORM.
   "B" IS VERTICAL DIFFERENCE BETWEEN PLATFORM AND VEHICLE FLOOR, MEASURED AT TOP EDGE OF PLATFORM.
   "C" IS THE HEIGHT OF CAR FLOOR FROM TOP OF RAIL:
   864mm [2'-10"] FOR LRV1 (BOEING-VERTOL)
   864mm [2'-10"] ±6mm [±1/4"] FOR LRV2 (BREDA)

REFERENCE:

1. CALIFORNIA STATE PUBLIC UTILITIES COMMISSION GENERAL ORDER 143-B; JANUARY 20, 2000
2. FEDERAL REGISTER PART IV, - DEPARTMENT OF TRANSPORTATION (49 CFR PART 27, 37 AND 38) TRANSPORTATION FOR INDIVIDUALS WITH DISABILITIES; FINAL RULE, SEPTEMBER 6,1991.
3. FEDERAL REGISTER PART II, - ARCHITECTURAL AND TRANSPORTATION BARRIERS COMPLIANCE BOARD (36 CFR PART 1191) AMERICAN WITH DISABILITIES ACT (ADA) ACCESSIBILITY GUIDELINES FOR BUILDINGS AND FACILITIES; TRANSPORTATION FACILITIES; AMENDMENT TO FINAL GUIDELINES, SEPTEMBER 6, 1991

COORDINATION OF VEHICLE FLOOR WITH BOARDING PLATFORM AT TANGENT AND CURVED TRACKS

LIGHT RAIL VEHICLE (LRV1 & LRV2)	PLATFORM	"A"	"B"	REFERENCE	
NEW	NEW	≤ 75mm [3"]	WITHIN ± 16mm [5/8"]	REF. 2, SEC. 38.73(d);	REF. 3, SEC. 10.3.1(9)
NEW	EXISTING (KEY STATION)	≤ 75mm [3"] AT KEY STATIONS AT ONE DOOR OF EACH NEW VEHICLE	WITHIN ± 38mm [1 1/2"]	REF. 2, SEC. 38.73(d);	REF. 3, SEC. 10.3.2(4)
RETROFITTED	NEW	≤ 100mm [4"]	WITHIN ± 50mm [2"] UNDER 50 % PASSENGER LOAD	REF. 2, SEC. 38.73(d);	----
RETROFITTED	EXISTING (KEY STATION)	≤ 100mm [4"]	WITHIN ± 50mm [2"] UNDER 50 % PASSENGER LOAD	REF. 2, SEC. 38.73(d);	REF. 3, SEC. 10.3.2(4)

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CITY AND COUNTY OF SAN FRANCISCO
MUNICIPAL RAILWAY

APPROVED

GENERAL MANAGER

LIGHT RAIL TRANSIT SYSTEM

VEHICLE CLEARANCES CASE (III)

CONTRACT MR-XXXX
DRAWING TR/CLR-04
REVISION 0
NTS

PROJ. NO./FILENAME : T:TRACK STD/LRV CLEARANCE/TR_CLR-04

3. LRV System Outline

APPENDIX A

APPENDIX A

Table of Contents

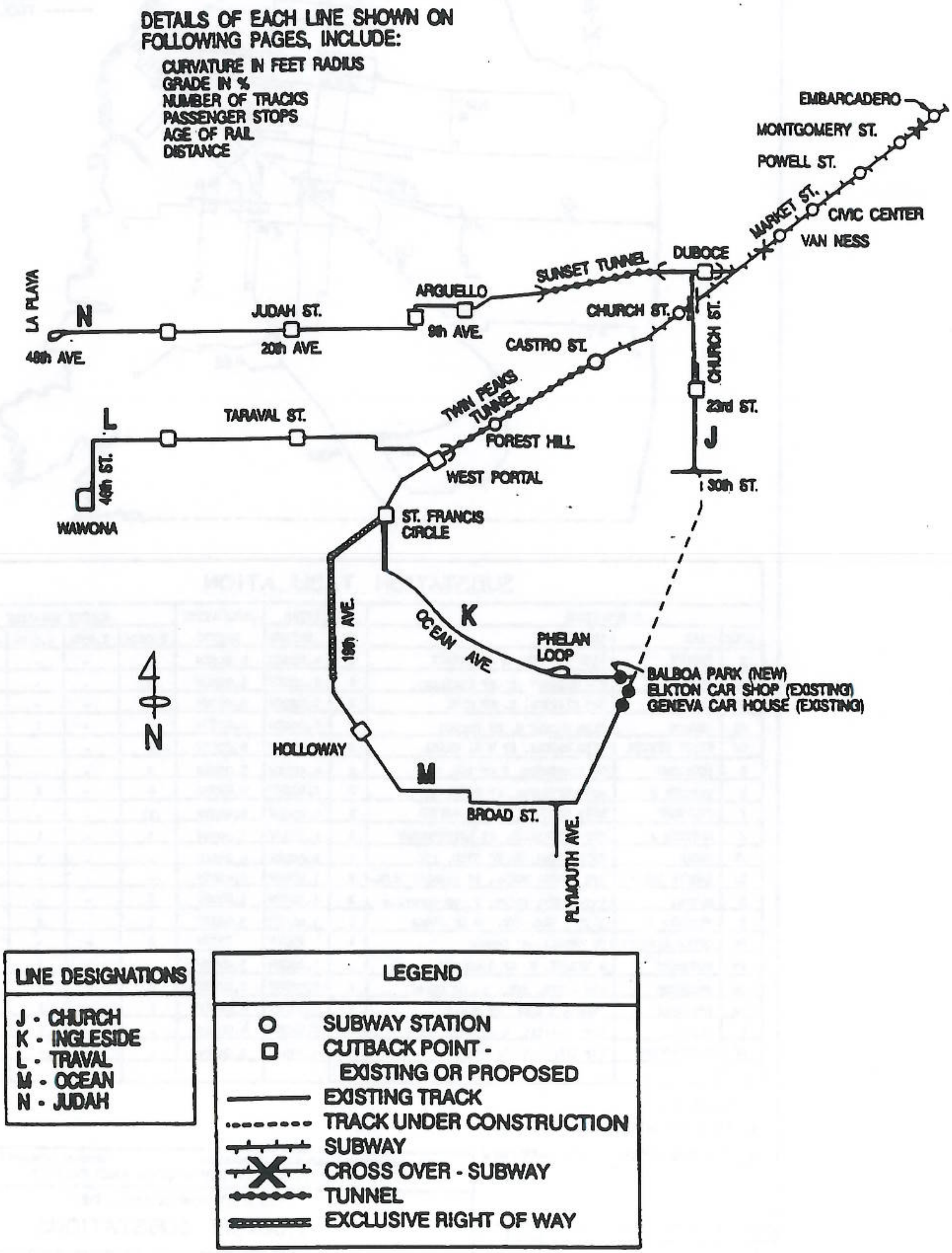
MUNI METRO TRANSIT SYSTEM DIAGRAM

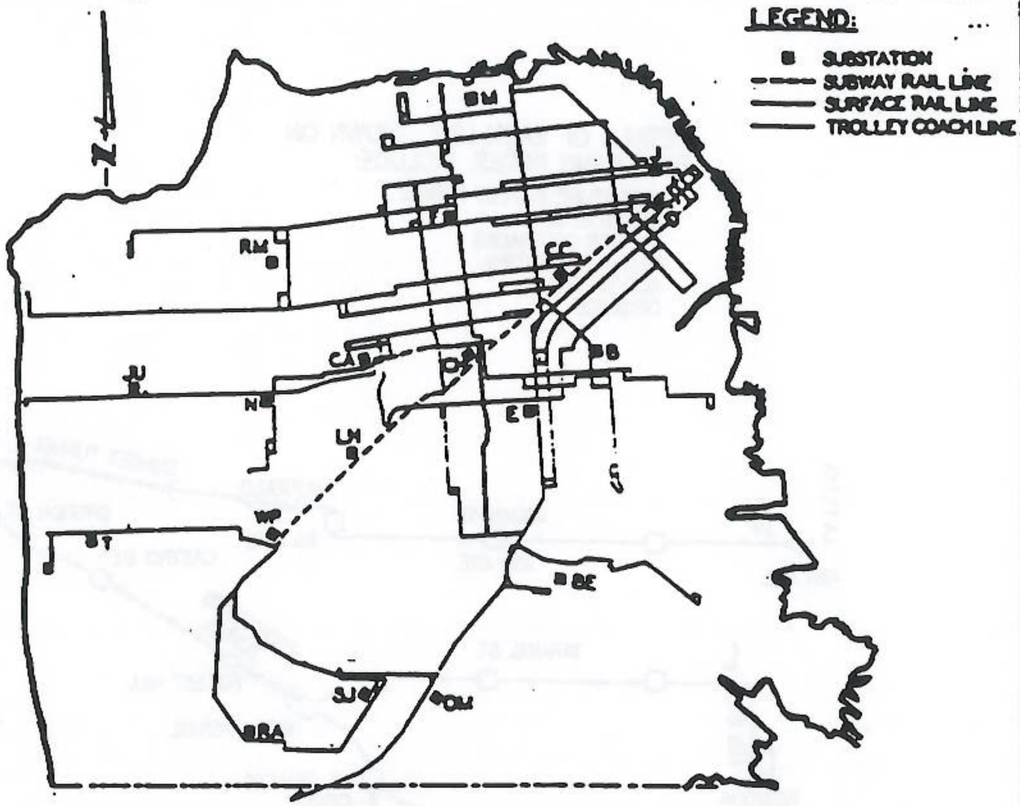
LOCATIONS OF MUNI TRANSIT POWER SUBSTATIONS

MUNI METRO TRACK TABLES

VERTICAL AND HORIZONTAL CURVES

CHORDS, DEFLECTION ANGLES AND OFFSETS


DETAILS OF EACH LINE SHOWN ON FOLLOWING PAGES, INCLUDE:
CURVATURE IN FEET RADIUS
GRADE IN %
NUMBER OF TRACKS
PASSENGER STOPS
AGE OF RAIL
DISTANCE
EMBARCADERO
MONTGOMERY ST.
POWELL ST.
MARKET ST.
CIVIC CENTER
VAN NESS
DUBOCE
SUNSET TUNNEL
ARGUELLO
CHURCH ST.
CHURCH ST.
LA PLAYA
N
JUDAH ST.
48th AVE.
20th AVE.
9th AVE.
CASTRO ST.
TWIN PEAKS TUNNEL
23rd ST.
L
TARAVAL ST.
FOREST HILL
J
48th ST.
WEST PORTAL
30th ST.
WAWONA
ST. FRANCIS CIRCLE
19th AVE.
K
OCEAN AVE.
PHELAN LOOP
BALBOA PARK (NEW)
ELKTON CAR SHOP (EXISTING)
GENEVA CAR HOUSE (EXISTING)
N
HOLLOWAY
M
BROAD ST.
PLYMOUTH AVE.
LINE DESIGNATIONS
J - CHURCH
K - INGLESIDE
L - TRAVAL
M - OCEAN
N - JUDAH
LEGEND
SUBWAY STATION
CUTBACK POINT - EXISTING OR PROPOSED
EXISTING TRACK
TRACK UNDER CONSTRUCTION
SUBWAY
CROSS OVER - SUBWAY
TUNNEL
EXCLUSIVE RIGHT OF WAY



SUBSTATION TABULATION

SUBSTATIONS			RECTIFIER		SUBSTATION	FEEDER BREAKERS				NOTES
CODE	NAME	LOCATION	NO.	RATING	RATING	2,000A	3,000A	4,000A	6,000A	
B	BRYANT	2502 ALAMEDA, E OF BRYANT	1	4,000KW	4,000KW	6	-	-	-	T
BE	BERNAL	425 ANDOVER, S. OF CORTLAND	1	1,000KW	1,000KW	3	-	-	-	T
CA	CARL	825 CLAYTON, N. OF CARL	2	3,000KW	6,000KW	2	-	-	2	S,T
CH	CHURCH	2130 MARKET W. OF CHURCH	2	4,000KW	8,000KW	5	-	1	5	S,T
CC	CIVIC CENTER	1190 MARKET, AT U.N. PLAZA	2	4,000KW	8,000KW	6	-	-	6	S,T
D	DOWNTOWN	79 STEVENSON, E OF 2ND. ST.	2	4,000KV	8,000KW	6	-	-	7	S,T
E	STATION E	200 LEXINGTON, AT 19TH. ST.	2	2,000KW	4,000KW	4	-	2	-	S,T
F	FILLMORE	1825 FILLMORE, N. OF SUTTER	2	4,000KW	8,000KW	12	-	-	-	T
J	STATION J	520 SACRAMENTO, AT LEIDESDORFF	2	1,500KW	3,000KW	4	-	1	-	T
JU	JUDAH	2710 JUDAH, E. OF 32ND. AVE.	1	4,000KW	4,000KW	-	-	3	-	S
LH	LAGUNA HONDA	375 LAGUNA HONDA, AT LAUNDRY BLDG.	2	3,000KW	6,000KW	-	-	-	5	S
M	MARINA	1575 NORTH POINT, E. OF BUCHANAN	2	1,500KW	3,000KW	6	-	-	-	T
N	STATION N	3037 - 9TH. AVE., S OF JUDAH	1	3,000KW	3,000KW	1	-	2	-	S,T
OM	OUTER MISSION	99 RUSSIA, AT LONDON	1	750KW	750KW	2	-	-	-	T
RA	RANDOLPH	8 BYXBEE, N. OF RANDOLPH	1	3,000KW	3,000KW	-	-	2	-	S
RM	RICHMOND	935 - 8TH. AVE., S. OF GEARY	1	2,000KW	2,000KW	2	2	-	-	T
SJ	SAN JOSE	2200 SAN JOSE, AT OCEAN	1	4,000KW	4,000KW	1	-	2	2	S,T
T	TARAVAL	3027 TARAVAL, W OF 40TH. AVE.	1	4,000KW	4,000KW	-	-	3	-	S
WP	WEST PORTAL	195 LENOX, N. OF ULLOA	2	3,000KW	6,000KW	-	-	3	4	S

NOTES

1. THIS DWG. SUPERSEDES DWG. K-7.
2. S = STREETCAR, T = TROLLEY COACH

CITY AND COUNTY OF SAN FRANCISCO — PUBLIC UTILITIES COMMISSION

HETCH HETCHY WATER AND POWER

TRANSIT POWER FACILITIES

TRANSIT SUBSTATIONS

GS		NONE	APR 83
RK		K-183	0

REVISIONS

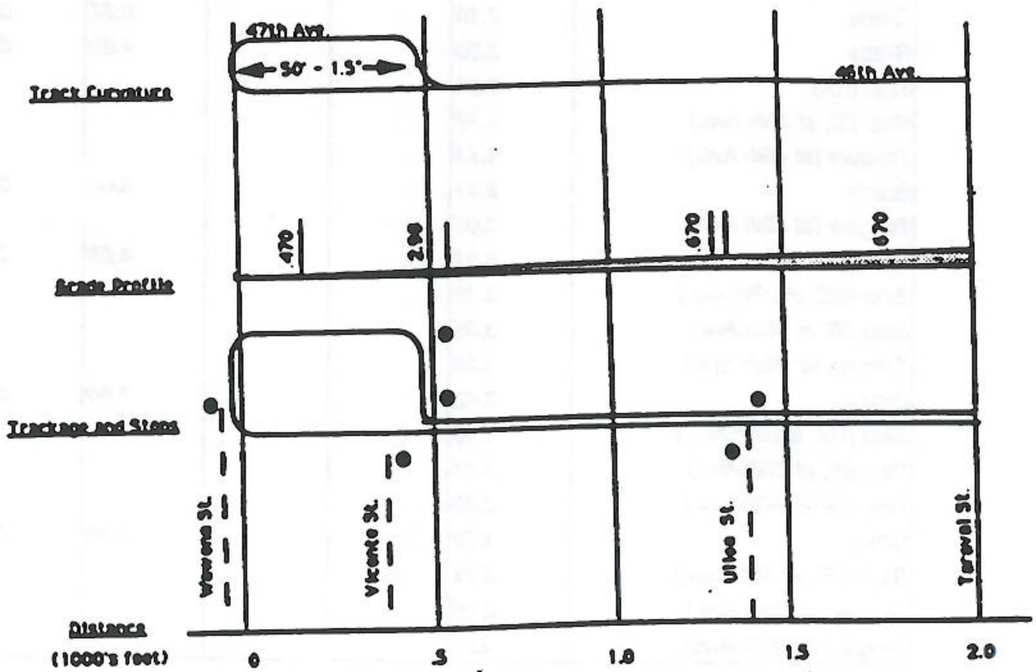
"L" - Taraval Line

Section 1: 46th Avenue - Wawona Street
(0 Distance at Taraval Street)
Distance in 1000's of Feet

Point of Change	Distance From Start	Curve Radius	Curve Length	Grade % (+ or -)	Grade Length	Tangent Length
Grade	0.00			0.47	0.45	
Curve (at 46th Ave.)	0.00	50' - 1.5°	0.08			
Stop (Wawona at 46th Ave.)	0.00					
Curve (at 47th Ave.)	0.00	50' - 1.5°	0.08			
Tangent (Wawona St.)	0.00					0.20
Grade	0.45			2.90	0.22	
Stop (46th at Vicente St.)	0.63					
Curve (at 47th Ave.)	0.70	50' - 1.5°	0.80			
Curve (at 46th Ave.)	0.70	50' - 1.5°	0.80			
Stop (Vicente at 47th Ave.)	0.74					
Stop (Vicente at 46th Ave.)	0.74					
Tangent (Vicente St.)						0.16
Grade	0.74			0.67	0.59	
Tangent	1.33					0.08
Stop (IB, at Ulloa St.)	1.33					
Grade	1.41			0.67	0.63	
Stop (OB, at Ulloa St.)	1.43					

Distance from Taraval Street to Wawona Street: 2,040 Ft.
Total Length of Track: 4,530 Ft.
Number of Stops: 6
Curves Length: 320 Ft.
Grade Length: 1,890 Ft.

46th Avenue - Wawona Street



"L" - Taraval Line

Section 2: Taraval St. from 48th Ave. to 15th Ave.
(0 Distance at 48th Ave.)

Point of Change	Distance From Start	Curve Radius	Curve Length	Grade % (+ or -)	Grade Length	Tangent Length
Grade	0.00			4.67	0.25	
End Single Track	0.00					
Beginning Double Track	0.11					
Tangent (at 47th Ave.)	0.25					0.09
Grade	0.34			3.75	0.26	
Turn Out (Wawona Loop)	0.60					
Tangent (at 46th Ave.)	0.60					0.06
Grade	0.66			5.00	0.25	
Stop (IB, at 46th Ave.)	0.68					
Stop (OB, at 46th Ave.)	0.68					
Stop (IB, at 45th Ave.)	0.89					
Tangent (at 45th Ave.)	0.91					0.07
Grade	0.98			5.00	0.25	
Tangent (at 44th Ave.)	1.25					0.06
Grade	1.31			5.00	0.25	
Stop (OB, at 44th Ave.)	1.32					
Stop (IB, at 43rd Ave.)	1.55					
Tangent (at 43rd Ave.)	1.56					0.08
Grade	1.61			5.00	0.20	
Stop (IB, at 42nd Ave.)	1.80					
Tangent (at 42nd Ave.)	1.81					0.07
Grade	1.88			1.50	0.23	
Stop (OB, at 42nd Ave.)	1.89					
Stop (IB, at 41st Ave.)	2.10					
Tangent (at 41st Ave.)	2.11					0.07
Grade	2.18			0.67	0.32	
Grade	2.50			4.83	0.24	
Stop (OB)	2.51					
Stop (IB, at 40th Ave.)	2.73					
Tangent (at 40th Ave.)	2.74					0.07
Grade	2.81			5.0[illegible]	0.24	
Tangent (at 39th Ave.)	3.05					0.06
Grade	3.11			4.68	0.25	
Stop (OB, at 39th Ave.)	3.12					
Stop (IB, at 38th Ave.)	3.35					
Tangent (at 38th Ave.)	3.36					0.06
Grade	3.42			2.50	0.23	
Stop (OB, at 38th Ave.)	3.43					
Stop (IB, at 37th Ave.)	3.64					
Tangent (at 37th Ave.)	3.65					0.08
Grade	3.73			2.08	0.24	
Stop (OB, at 37th Ave.)	3.74					
Stop (IB, at 35th Ave.)	3.96					
Tangent (at 35th Ave.)	3.97					0.06

Section 2: Taraval St. from 48th Ave. to 15th Ave. (continued)
(0 Distance at 48th Ave.)

Point of Change	Distance From Start	Curve Radius	Curve Length	Grade % (+ or -)	Grade Length	Tangent Length
Grade	4.03			2.08	0.26	
Tangent (at 34th Ave.)	4.29					0.06
Grade	4.35			6.66	0.25	
Stop (OB, at 34th Ave.)	4.36					
Stop (IB, at 33rd Ave.)	4.59					
Tangent (at 33rd Ave.)	4.60					0.08
Grade	4.68			2.50	0.25	
Crossover	4.81					
Tangent (at 32nd Ave.)	4.93					0.09
Grade	5.02			6.25	0.23	
Stop (OB, at 32nd Ave.)	5.03					
Stop (IB, at 31st Ave.)	5.24					
Tangent (at 31st Ave.)	5.25					0.06
Grade	5.31			8.96	0.24	
Stop (IB, at 30th Ave.)	5.54					
Tangent (at 30th Ave.)	5.55					0.05
Grade	5.60			7.08	0.24	
Stop (OB, at 30th Ave.)	5.61					
Stop (IB, at 29th Ave.)	5.83					
Tangent (at 29th Ave.)	5.84					0.05
Grade	5.89			8.96	0.24	
Tangent (at 28th Ave.)	6.13					0.05
Grade	6.18			4.17	0.25	
Stop (OB, at 28th Ave.)	6.19					
Stop (IB, at 27th Ave.)	6.42					
Tangent (at 27th Ave.)	6.43					0.05
Grade	6.48			2.08	0.26	
Tangent (at 26th Ave.)	6.74					0.05
Grade	6.79			7.08	0.27	
Stop (OB, at 26th Ave.)	6.80					
Stop (IB, at 25th Ave.)	7.05					
Tangent (at 25th Ave.)	7.06					0.05
Grade	7.11			6.25	0.24	
Stop (OB, at 25th Ave.)	7.12					
Stop (IB at 24th Ave.)	7.34					
Tangent (at 24th Ave.)	7.35					0.08
Grade	7.43			6.25	0.24	
Stop (OB, at 24th Ave.)	7.44					
Stop (IB, at 23rd Ave.)	7.66					
Tangent (at 23rd Ave.)	7.67					0.06
Grade	7.73			4.17	0.24	
Tangent (at 22nd Ave.)	7.97					0.08
Grade	8.05			4.17	0.25	
Stop (OB, at 22nd Ave.)	8.06					

"L" - Taraval Line

Section 2: Taraval St. from 48th Ave. to 15th Ave. (continued)
(0 Distance at 48th Ave.)

Point of Change	Distance From Start	Curve Radius	Curve Length	Grade % (+ or -)	Grade Length	Tangent Length
Stop (IB, at 21st Ave.)	8.29					
Tangent (at 21st Ave.)	8.30					0.07
Grade	8.37			3.75	0.25	
Stop (IB, at 20th Ave.)	8.61					
Tangent (at 20th Ave.)	8.62					0.07
Crosover	8.62					
Turn Around	8.68					
Grade	8.69			7.60	0.25	
Stop (OB, at 20th Ave.)	8.70					
Crossover	8.83					
Stop (IB, at 19th Ave.)	8.93					
Tangent (at 19th Ave.)	8.94					0.06
Grade	9.00			7.00	0.24	
Stop (OB, at 19th Ave.)	9.01					
Tangent (at 18th Ave.)	9.24					0.07
Grade	9.31			5.80	0.26	
Stop (OB, at 18th Ave.)	9.32					
Stop (IB, at 17th Ave.)	9.56					
Tangent (at 17th Ave.)	9.57					0.06
Grade	9.63			7.10	0.25	
Tangent (at 16th Ave.)	9.88					0.05
Grade	9.93			8.60	0.27	
Stop (OB, at 16th Ave.)	9.94					
Stop (IB, at 15th Ave.)	10.19					
Tangent (at 15th Ave.)	10.20					0.03

Total Length of Section 2: 10,230 Ft.
Tangent : 2,040 Ft.
Grade: 8,190 Ft.

"L" - Taraval Line

Section 3: 15th Ave. from Taraval St. to Ulloa St.

Point of Change	Distance From Start	Curve Radius	Curve Length	Grade % (+ or -)	Grade Length	Tangent Length
Curve (right)	10.23	42' - 7.5"	0.09			
Tangent (at 15th Ave.)	10.23					0.03
Grade	10.26			-0.70	0.65	
Tangent	10.91					0.07
Stop (OB, at Ulloa St.)	10.91					
Stop (IB, at Ulloa St.)	10.91					
Curve (left)	10.93	42' - 7.5"	0.10			
Grade				-5.90	0.05	

Total Length of Section 3: 800 Ft.
Tangent: 60 Ft.
Grade: 650 Ft.

"L" - Taraval Line

Section 4: Ulloa St. from 15th Ave. to Twin Peaks Tunnel

Point of Change	Distance From Start	Curve Radius	Curve Length	Grade % (+ or -)	Grade Length	Tangent Length
Grade	11.03			-5.90	0.19	
Tangent (at 14th Ave.)	11.22					0.06
Grade	11.28			-5.00	0.24	
Stop (WB, at 14th Ave.)	11.29					
Tangent (at Funston Ave.)	11.52					0.08
Grade	11.60			-4.17	0.51	
Stop (EB, at Forest Side)	11.60					
Stop (WB, at Forest Side)	11.70					
Curve (right)	11.76	375 Ft.	0.57			
Stop (EB, at Madrone Ave.)	11.79					
Crossover	12.10					
Grade	12.11			-1.52	0.43	
Turn Out (K&M Line)	12.28					
Curve (left)	12.28	42' - 7.5"	0.9			
Stop (EB, at Portal)	12.48					
Stop (WB, at Portal)	12.48					
Entry (Twin Peak Tunnel)	12.54				1.37	

Total Length of Section 4: 1,510 Ft.
Tangent: 160 Ft.
Grade: 1,420 Ft.

SUMMARY
"L" - Taraval Line

Total Length: 46th Ave - Wawona St Loop:	*2,040 Ft. (Along 46th Ave.)*			
Total Length: Sections: 2,3,&4:	*12,540 Ft.*			
Tangent: 46th Ave - Wawona St Loop:	*440 Ft. (Along Wawona St. & Vincente St.)*			
	150 Ft. (Along 46th Ave.)			
Tangent: Sections: 2, 3 & 4:	*2,260 Ft.*			
Grade Length: 46th Ave - Wawona St Loop:		*1.89 Ft.*	*up 1%*	*1,670 Ft.*
			2% to 3%	*220 Ft.*
Grade Length: Sections: 2,3 &4:	*up 1%*	*970 Ft.*		
	1% to 2%	*660 Ft.*		
	2% to 3%	*1,240 Ft.*		
	3% to 4%	*510 Ft.*		
	4% to 5%	*1,990 Ft.*		
	5% to 6%	*1,950 Ft.*		
	6% to 7%	*960 Ft.*		
	7% to 8%	*1,250 Ft.*		
	8% up	*750 Ft.*		
Curve Length: 46th Ave - Wawona St Loop:	*320 Ft.*	*Radius*	*50' - 1.5"*	
Curve Length: Sections 2, 3 & 4:	*1,669, Ft.*	*Radius*	*42' - 7.5"*	*1,090 Ft.*
			375 Ft.	*570 Ft.*
Number of Stops: 46th Ave - Wawona St Loop:		*3*	*Min Distance:*	*187 Ft.*
			Max Distance:	*830 Ft.*
			Avr. Distance:	*755 Ft.*
In Bound		*3*	*Min Distance:*	*238 Ft.*
			Max Distance:	*663 Ft.*
			Avr Distance:	*482 Ft.*
Number of Stops: Sections: 2,3 & 4:		*24*	*Min Distance:*	*263 Ft.*
Out Bound			*Max Distance:*	*675 Ft.*
			Avr. Distance:	*523 Ft.*

"K" - Ingleside Line

Section 1: West Portal Ave. to Junipero Serra Boulevard

Distance in 1000's of Feet

Point of Change	Distance From Start	Curve Radius	Curve Length	Grade % (+ or -)	Grade Length	Tangent Length
Tangent	0.00			0.00		0.50
Turn Out (L Line)	0.20					
Stop (IB at Ulloa St.)	0.22					
Stop (OB at Ulloa St.)	0.25					0.08
Grade	0.50			-2.80	0.69	
Stop (OB at Santa Clara Ave.)	0.56					
Stop (IB at Santa Clara Ave.)	0.63					
Grade	1.19			-3.00	0.41	
Stop (OB at 14th Ave.)	1.41					
Stop (IB at 14th Ave.)	1.52					
Grade	1.60			-2.95	0.53	
Curve (right)	1.79	1270 Ft	0.57			
Stop (OB at 15th Ave.)	2.10					
Grade	2.13			-3.30	0.09	
Stop (IB at 15th Ave.)	2.16					
Grade	2.22			-3.15	0.28	
Grade	2.50			-2.25	0.31	
Crossover	2.50					
Stop (IB)	2.54					
Curve (right)	2.77	190 Ft	0.08			
Grade	2.81			-1.16	0.28	
Turn Out (M Line)	2.83					

Length of Section 1: 2,830 Ft.
Tangent Length: 500 Ft.
Grade Length: 2,330 Ft.
Curve Length: 650 Ft.

"K" - Ingleside Line

Section 2: Junipero Serra Boulevard from St. Francis Blvd. to Ocean Ave.

Point of Change	*Distance From Start*	*Curve Radius*	*Curve Length*	*Grade % (+ or -)*	*Grade Length*	*Tangent Length*
Stop (IB at St. Francis)	*3.03*					
Grade	*3.09*			*-1.87*	*1.21*	
Stop (OB at St. Francis)	*3.09*					
Stop (OB at Darien Way)	*4.01*					
Curve (right)	*4.01*	*220 Ft*	*0.24*			
Grade	*4.30*			*3.00*	*0.29*	
Stop (IB)	*4.34*					

Length of Section 2: 1,510 Ft.
Tangent Length: 0 Ft.
Grade Length: 1,510 Ft.

"K" - Ingleside Line

Section 3: Ocean Ave. from Junipero Serra Blvd. to Geneva Ave.

Point of Change	*Distance From Start*	*Curve Radius*	*Curve Length*	*Grade % (+ or -)*	*Grade Length*	*Tangent Length*
Grade	*4.59*			*2.86*	*0.41*	
Stop (OB at St. Fernando)	*4.71*					
Stop (IB at St. Fernando)	*4.78*					
Grade	*5.00*			*2.90*	*0.25*	
Curve (left)	*5.16*	*820 Ft*	*0.21*			
Curve (left)	*5.37*	*500 Ft*	*0.22*			
Grade	*5.25*			*1.13*	*0.18*	
Stop (OB at Paloma Av)	*5.40*					
Grade	*5.43*			*3.80*	*0.18*	
Stop (IB at Paloma Av)	*5.50*					
Grade	*5.61*			*2.95*	*0.15*	
Stop (OB at Aptos Av)	*5.73*					
Tangent	*5.76*			*0.00*		*0.33*
Stop (IB at Aptos Av)	*5.81*					
Curve (right)	*5.81*	*1386 Ft*	*0.48*			
Grade	*6.09*			*-4.60*	*0.29*	
Stop (OB at Ceritos Av)	*6.28*					
Curve (right)	*6.33*	*2813 Ft*	*0.28*			
Stop (IB at Ceritos)	*6.35*					
Grade	*6.38*			*-2.80*	*0.11*	
Grade	*6.49*			*-3.20*	*0.04*	
Grade	*6.53*			*-4.57*	*0.29*	
Curve (right)	*6.69*	*1103 Ft*	*0.33*			
Grade	*6.82*			*-3.30*	*0.07*	
Grade	*6.89*			*-0.78*	*0.85*	
Stop (OB at Fairfield Dr)	*7.13*					

"K" - Ingleside Line

Section 3: Ocean Ave. from Junipero Serra Blvd. to Geneva Ave. (continued)

Point of Change	Distance From Start	Curve Radius	Curve Length	Grade % (+ or -)	Grade Length	Tangent Length
Curve (left)	7.26	3000 Ft	0.17			
Stop (IB at Fairfield Dr)	7.26					
Stop (OB at Keystone Wy)	7.74					
Tangent	7.74			0.00		0.09
Stop (IB at Keystone Wy)	7.83					
Grade	7.83			-0.60	0.23	
Curve (left)	7.83	5000 Ft	0.15			
Tangent	8.06			0.00		0.07
Stop (OB Ashton Ave)	8.09					
Grade	8.13			-2.65	0.23	
Curve (right)	8.16	1500 Ft	0.21			
Stop (IB at Ashton Ave)	8.16					
Grade	8.36			-0.87	0.10	
Grade	8.46			2.68	0.21	
Grade	8.67			0.87	0.08	
Grade	8.75			2.68	0.22	
Stop (OB at Capitol Ave)	8.94					
Grade	8.97			0.87	0.09	
Stop (IB at Capitol Ave)	9.06					
Grade	9.06			2.44	0.22	
Grade	9.28			1.15	0.07	
Grade	9.35			0.20	0.24	
Stop (OB at Granada Ave)	9.59					
Grade	9.59			1.15	0.07	
Grade	9.66			3.20	0.22	
Stop (IB at Granada Ave)	9.66					
Turn Out	9.88					
Grade	9.88			1.37	0.34	
Stop (OB at Lee Ave)	10.15					
To Balboa Park Sta.	10.22					
Turn Out (loop)	10.22					
Stop (IB loop)	10.29					

Length of Section 3: 5,950 Ft

Tangent Length: 490 Ft.

Grade Length: 5,460 Ft.

SUMMARY
"K" - Ingleside Line

Total Length of K Line:	*10,220 Ft.*	*(Double Track)*
Tangent Length:	*990 Ft.*	*(Double Track)*

Grade Length: 9,230 Ft.

up 1%	*1,590 Ft.*
1% to 2%	*2,150 Ft.*
2% to 3%	*3,330 Ft.*
3% to 4%	*1,580 Ft.*
4% to 5%	*580 Ft.*

Curve Length: 2,940 Ft.

up to 200 Ft	*80 Ft.*
200 Ft to 300 Ft	*0 Ft.*
300 Ft to 500 Ft	*670 Ft.*
500 Ft to 1K Ft	*0 Ft.*
1K Ft to 2K Ft	*1,590 Ft.*
2KFt to 3K Ft	*450 Ft.*
3K Ft up	*150 Ft.*

Number of Stops: 17 (Outbound)

Min Distance Between Stops:	*310 Ft.*
Max Distance Between Stops:	*1,010 Ft.*
Avr Distance Between Stops:	*600 Ft.*

Number of Stops: 16 (Inbound)

Min Distance Between Stops:	*360 Ft.*
Max Distance Between Stops:	*1,310 Ft.*
Avr Distance Between Stops:	*640 Ft.*

Section 1: Right of Way from St. Francis Blvd to Ocean Ave
Distance in 1000's of Feet

Point of Change	Distance From Start	Curve Radius	Curve Length	Grade % (+ or -)	Grade Length	Tangent Length
Stop (IB at St. Francis)	0.00					
Grade	0.00			-2.70	0.09	
Stop (OB at St. Francis)	0.06					
Turn Out (K Line)	0.08					
Grade	0.09			-3.50	0.13	
Grade	0.22			-3.20	0.06	
Grade	0.28			-2.64	0.07	
Stop (IB at Woodacre Cre)	0.30					
Stop (OB at Woodacre Cre)	0.31					
Grade	0.35			-3.50	1.85	
Stop (OB at Beachmont Dr)	1.21					
Stop (IB at Beachmont Dr)	1.25					
Stop (OB at Ocean Ave.)	1.50					
Stop (IB at Ocean Ave.)	1.54					
Curve (left)	1.60	1146 Ft	0.45			

Length of Section 1: 2,050 Ft.
Tangent Length: 0 Ft.
Grade Length: 2,050 Ft.

Section 2: 19th Ave. from Ocean Ave. to Randolph St.

Point of Change	Distance From Start	Curve Radius	Curve Length	Grade % (+ or -)	Grade Length	Tangent Length
Stop (OB at Rossmoor Dr)	2.06					
Stop (IB at Rossmoor Dr)	2.06					
Grade	2.20			-2.34	1.87	
Stop (OB at Mercedes Dr)	2.94					
Stop (IB at Mercedes Dr)	2.94					
Stop (OB at Serra Plgd)	3.79					
Stop (IB at Serra Plgd)	3.83					
Grade	4.07			-0.03	0.43	
Grade	4.50			2.00	1.21	
Stop (OB at SF State Univ)	4.85					
Stop (IB at SF State Univ)	4.85					
Curve (left)	5.50	300 Ft	0.35			
Stop (OB at Holloway Ave)	5.57					
Stop (IB at Holloway Ave)	5.57					
Grade	5.71			5.85	0.25	
Stop (OB at Banbury)	5.91					
Stop (IB at Banbury)	5.91					
Grade	5.96			4.85	0.40	
Crossover	6.00					

"M" - Oceanview Line

Section 2: 19th Ave. from Ocean Ave. to Randolph St. (continued)

Point of Change	Distance From Start	Curve Radius	Curve Length	Grade % (+ or -)	Grade Length	Tangent Length
Stop (OB at Cardenas Ave)	6.28					
Stop (IB at Cardenas Ave)	6.28					
Grade	6.36			3.02	0.57	
Tangent B	6.93					0.18
Stop (OB at Junipero Serra)	6.88					
Stop (IB at Junipero Serra)	6.88					
Stop (IB)	7.06					
Grade	7.11			2.47	0.35	
Stop (IB at Sargent St)	7.42					
Grade	7.46			0.76	0.52	
Stop (IB at Monticello St)	7.81					
Grade	7.98			1.92	0.35	
Stop (OB at Byxbee)	7.98					
Stop (OB at Randolph St)	8.25					
Stop (IB at Randolph St)	8.25					

Length of Section 2: 6,200 Ft.
Tangent Length: 180 Ft.
Grade Length: 1,020 Ft.

"M" - Oceanview Line

Section 3: Randolph St. from 19th Ave to Orizaba Ave

Point of Change	Distance From Start	Curve Radius	Curve Length	Grade % (+ or -)	Grade Length	Tangent Length
Curve (right)	4.59			2.86	0.41	
Grade	4.71					
Grade	4.78					
Grade	5.00			2.90	0.25	
Stop (OB at Arch St)	5.16	820 Ft	0.21			
Stop (IB at Arch St)	5.37	500 Ft	0.22			
Grade	5.25			1.13	0.18	
Stop (OB at Head St)	5.40					
Grade	5.43			3.80	0.18	
Stop (IB at Head St)	5.50					
Grade	5.61			2.95	0.15	
Grade	5.73					

Length of Section 3: 1,940 Ft
Tangent Length: 0 Ft.
Grade Length: 1,940 Ft.

"M" - Oceanview Line

Section 4: Orizaba Ave from Randolph St to Broad St.

Point of Change	Distance From Start	Curve Radius	Curve Length	Grade % (+ or -)	Grade Length	Tangent Length
Curve (left)	10.33	58 Ft	0.08			
Stop (OB at Farallones)	10.37					
Stop (IB at Farallones)	10.37					
Grade	10.35			-5.09	0.08	
Grade	10.43			-7.33	0.23	
Curve (right)	10.45	250 Ft	0.09			
Grade	10.66			-4.18	0.30	
Curve (left)	10.72	50 Ft	0.10			

Lenght of Section 4: 490 Ft
Tangent Length: 0 Ft
Grade Length: 490 Ft

"M" - Oceanview Line

Section 5: Broad St from Orizaba Ave to Plymouth Ave

Point of Change	Distance From Start	Curve Radius	Curve Length	Grade % (+ or -)	Grade Length	Tangent Length
Stop (OB at Orizaba Ave)	10.82					
Stop (IB at Orizaba Ave)	10.82					
Grade	10.96			3.00	0.22	
Grade	11.18			2.24	0.47	
Stop (OB at Capitol Ave)	11.65					
Grade	11.65			1.60	0.08	
Grade	11.73			1.25	0.27	
Stop (IB at Capitol Ave)	11.73					
Grade	12			-0.35	0.50	
Crossover	12.5					
Turn Around	12.6					
Stop (IB at Plymouth)	12.75					
End Track	12.85					

Length of Section 5: 2,030 Ft.
Tangent Length: 0 Ft.
Grade Length: 2,030 Ft.

SUMMARY
"M" - Oceanview Line

Total Length of M Line:	***12,500 Ft.***	***(Double Track)***	
Tangent Length:	***180 Ft.***	***(Double Track)***	
Grade Length:	***12,320 Ft.***		
		up to 1%	***2,020 Ft.***
		1% to 2%	***880 Ft.***
		2% to 3%	***4,060 Ft***
		3% to 4%	***2,980 Ft.***
		4% to 5%	***1,240 Ft.***
		5% to 6%	***330 Ft.***
		6% to 7%	***600 Ft.***
		7% up	***230 Ft.***
Curve Length:	***1,150 Ft.***	***up 250'***	***260 Ft.***
		200' to 300	***440 Ft.***
		1K Ft up	***450 Ft.***

Number of Stops:	***19***	***Min Distance Between Stops:***	***250 Ft.***
(Outbound)		***Max Distance Between Stops:***	***1,000 Ft.***
		Avr Distance Between Stops:	***660 Ft.***
Number of Stops:	***22***	***Min Distance Between Stops:***	***190 Ft.***
(Inbound)		***Max Distance Between Stops:***	***1,000 Ft.***
		Avr Distance Between Stops:	***580 Ft.***

Twin Peaks Tunnel, K, L & M Lines

Section 1: From West Portal to East Portal
Distance in 1000's of Feet

Point of Change	Distance From Start	Curve Radius	Curve Length	Grade % (+ or -)	Grade Length	Tangent Length
Grade	0.04			-2.72	0.31	
West Portal	0.09					
Grade	0.35			1.50	2.89	
Curve (left)	1.73	5,729.65'	1.31			
Grade	3.00			-1.50	0.39	
Forest Hill Station	3.11					
Grade	3.39			-3.00	1.01	
Grade	4.40			-2.70	0.30	
Grade	4.70			-3.00	2.80	
Grade	7.50			-3.00	2.11	
Grade	9.61			-2.87	1.11	
Curve (left)	10.36	1,017.95'	0.45			
Grade	10.72			-2.10	0.50	
Grade	11.22			-1.40	0.14	
Grade	11.36			-5.00	0.39	
Curve (right)	11.49	1,000'	0.26			
East Portal	11.75					

Total Length of Section 1: 11,750 Ft.
Tangent Length: 0
Grade Length: 11,750 Ft.

SUMMARY
Twin Peaks Tunnel, K, L & M Lines

Total Length:	*11,750 Ft.*	*(Double Track)*		
Tangent Length:	*0 Ft.*	*(Double Track)*		
Grade Length:	*11,750 Ft.*		*up 1%*	*0 Ft.*
			1% to 2%	*3,220 Ft.*
			2% to 3%	*2,220 Ft.*
			3% to 4%	*5,920 Ft.*
			4% to 5%	*0 Ft.*
			5% up	*390 Ft.*
Curve Length:	*2,020 Ft.*	*Radius*	*up 1K*	*0 Ft.*
		Radius	*1K to 2K*	*450 Ft.*
			2K to 3K	*0 Ft.*
			3K to 4K	*0 Ft.*
			4K to 5K	*0 Ft.*
			up 5K	*1,310 Ft.*

"J" - Church Line

Section 1: Church Street from 30th St. to 22nd St.
Distance in 1000's of Feet

Point of Change	Distance From Start	Curve Radius	Curve Length	Grade % (+ or -)	Grade Length	Tangent Length
Grade	0.00			-2.90	0.27	
Stop (IB at 30th St.)	0.08					
Stop (OB at 30th St.)	0.08					
Tangent (at Day St.)	0.27					0.08
Grade	0.35			-1.30	0.23	
Stop (IB at 29th St.)	0.57					
Tangent (at 29th St.)	0.58					0.08
Grade	0.66			-1.10	0.22	
Stop (OB at 29th St.)	0.67					
Tangent (at Valley St.)	0.88					0.11
Grade	0.99			-1.50	0.18	
Stop (IB at 28th St.)	1.16					
Tangent (at 28th St.)	1.17					0.07
Grade	1.24			-3.50	0.24	
Stop (OB at 28th St.)	1.25					
Tangent (at Dunan St.)	1.48					0.06
Grade	1.54			1.30	0.20	
Stop (IB at 27th St.)	1.73					
Tangent (at 27th St.)	1.74					0.07
Grade	1.81			1.30	0.22	
Stop (OB at 27th St.)	1.82					
Tangent (at Army St.)	2.03					0.06
Grade	2.09			0.90	0.20	
Stop (IB at 26th St.)	2.28					
Tangent (at 26th St.)	2.29					0.05
Grade	2.34			1.30	0.22	
Tangent (at Clipper St.)	2.56					0.07
Grade	2.63			4.40	0.21	
Tangent (at 25th St.)	2.84					0.05
Grade	2.89			8.80	0.23	
Stop (OB at 25th St.)	2.90					
Tangent (at Jersey St.)	3.12					0.07
Grade	3.19			6.10	0.21	
Stop (IB at 24th St.)	3.39					
Tangent (at 24th St.)	3.40					0.06
Grade	3.46			4.60	0.54	
Stop (OB at 24th St.)	3.47					
Stop (IB at 23rd St.)	3.99					
Tangent (at 23rd St.)	4.00					0.06
Grade	4.06			3.40	0.44	
Stop (OB at 23rd St.)	4.07					

"J" - Church Line

Section 1: Church Street from 30th St. to 22nd St. (continued)

Point of Change	Distance From Start	Curve Radius	Curve Length	Grade % (+ or -)	Grade Length	Tangent Length
Stop (IB at 22nd St.)	4.49					
Tangent (at 22nd St.)	4.50					0.08
Grade	4.58			1.90	0.02	
Stop (OB at 22nd St.)	4.59					
End (Section 1)	4.60					

Length of Section 1: 4,600 Ft.
Tangent Length: 970 Ft.
Grade Length: 3,630 Ft.

"J" - Church Line

Section 2: Private Right-of-Way from 22nd to 18th St.

Point of Change	Distance From Start	Curve Radius	Curve Length	Grade % (+ or -)	Grade Length	Tangent Length
Curve (left)	4.60	150 Ft.	0.10			
Grade	4.60			1.90	0.28	
Curve (right)		150 Ft.	0.10			
Grade	4.88			2.30	0.28	
Curve (left)	5.02	128"	0.13			
Curve (right)		200 Ft.	0.16			
Grade	5.16			2.34	0.16	
Stop (IB at 21st St.)	5.27					
Grade	5.32			-7.80	0.26	
Stop (OB at 21st St.)	5.33					
Grade	5.58			-1.56	0.06	
Curve (right)	5.59	100 Ft.	0.14			
Grade	5.64			-7.50	0.20	
Curve (left)	5.78	120 Ft.	0.17			
Grade	5.84			-5.19	0.11	
Grade	5.95			-5.19	0.08	
Stop (IB at 20th St.)	6.03					
Grade	6.03			-1.55	0.06	
Grade	6.09			-9.00	0.46	
Stop (OB at 20th St.)	6.12					
Stop (IB at 19th St.)	6.53					
Grade	6.55			-3.00	0.06	
Grade	6.61			-8.79	0.60	
Stop (OB at 19th Ave.)	6.61					
Curve (right)	6.88	740 Ft.	0.22			
Curve (left)	7.16	95 Ft.	0.05			
Stop (IB at 18th St.)	7.20					
End (Section 3)	7.21					

"J" - Church Line

Section 2: Private Right-of-Way from 22nd to 18th St. (continued)

Length of Section 2: 2,610 Ft.
Tangent Length: 0 Ft.
Grade Length: 2,610 Ft.

"J" - Church Line

Section 3: Church St. from 18th St. to Duboce St.

Point of Change	Distance From Start	Curve Radius	Curve Length	Grade % (+ or -)	Grade Length	Tangent Length
Curve (left)	7.21	95 Ft.	0.04			
Tangent (at 18th Ave.)	7.21					0.04
Grade	7.25			7.70	0.30	
Stop (OB at 18th Ave.)	7.26					
Grade	7.55			4.80	0.26	
Stop (IB at 17th St.)	7.80					
Tangent (at 17th St.)	7.81					0.07
Grade	7.88			1.70	0.21	
Stop (OB at 17th St.)	7.89					
Tangent	8.09					0.03
Grade	8.12			1.00	0.29	
Stop (IB at 16th St.)	8.40					
Tangent (at 16th St.)	8.41					0.09
Grade	8.50			0.40	0.41	
Stop (OB at 16th St.)	8.51					
Stop (IB at 15th St.)	8.90					
Tangent (at 15th St.)	8.91					0.12
Grade	9.03			0.50	0.47	
Stop (OB at 15th St.)	9.04					
Stop (IB at Market St.)	9.30					
Grade	9.50			1.00	0.14	
Grade	9.64			3.00	0.31	
Grade	9.95			3.20	0.24	
Stop (IB at Duboce St.)	10.09					
Stop (OB at Duboce St.)	10.09					
Curve (left)	10.18	50 Ft.	0.10			
Tangent (at Duboce St.)	10.19					0.09
End of Line	10.28					

Length of Section 3: 3,070 Ft.
Tangent Length: 440 Ft.
Grade Length: 2,360 Ft.

SUMMARY

"J" - Church Line

Total Length of J Line:	*10,280 Ft.*	*(Double Track)*	
Tangent Length:	*1,410 Ft.*	*(Double Track)*	
Grade Length: 8,870 Ft.			
		up 1%	*1,080 Ft.*
		1% to 2%	*2,330 Ft.*
		2% to 3%	*710 Ft.*
		3% to 4%	*1,290 Ft.*
		4% to 5%	*1,010 Ft.*
		5% to 6%	*190 Ft.*
		6% to 7%	*210 Ft.*
		7% to 8%	*760 Ft.*
		8% to 9%	*830 Ft.*
		9% up	*460 Ft.*
Curve Length: 1,250 Ft.	*Radius*	*0' - 100'*	*190 Ft.*
	Radius	*100' - 200'*	*640 Ft.*
		200' - 300'	*160 Ft.*
		700' up	*220 Ft.*
Number of Stops (In Bound):	*17*	*Min Distance*	*425 Ft.*
		Max Distance	*1,044 Ft.*
		Avr Distance	*605 Ft.*
Number of Stops (Out Bound):	*16*	*Min Distance*	*475 Ft.*
		Max Distance	*1,163 Ft.*
		Avr Distance	*642 Ft.*

"N" - Judah Line

Section 1: From La Playa to 9th Ave.
Distance in 1000's of Feet

Point of Change	Distance From Start	Curve Radius	Curve Length	Grade % (+ or -)	Grade Length	Tangent Length
Loop (at La Playa)	0.00					
Curve (Loop)	0.00	50' - 1.5°	0.10			
Tangent (at La Playa)	0.00					0.08
Stop (IB)	0.03					
Grade	0.08			3.00	0.23	
Stop (OB)	0.09					
End (straight track)	0.09					
Stop (IB)	0.03					
Tangent (at 48th Ave.)	0.31					0.08
Grade	0.39			3.30	0.24	
Stop (OB)	0.40					
Crossover	0.41					
Stop (IB)	0.60					
Tangent (at 47th Ave.)	0.63					0.05
Grade	0.68			5.40	0.23	
Stop (OB)	0.69					
Stop (IB)	0.90					
Tangent (at 46th Ave.)	0.91					0.07
Grade	0.98			6.20	0.23	
Stop (OB)	0.99					
Stop (IB)	1.20					
Tangent (at 45th Ave.)	1.21					0.05
Grade	1.26			3.70	0.24	
Stop (OB)	1.27					
Stop (IB)	1.49					
Tangent (at 44th Ave.)	1.50					0.06
Grade	1.56			3.70	0.25	
Stop (OB)	1.57					
Stop (IB)	1.80					
Tangent (at 43rd Ave.)	1.81					0.04
Grade	1.85			3.70	0.26	
Stop (OB)	1.86					
Stop (IB)	2.10					
Tangent (at 42nd Ave.)	2.11					0.05
Grade	2.16			4.50	0.25	
Stop (OB)	2.17					
Stop (IB)	2.40					
Tangent (at 41st Ave.)	2.41					0.08
Grade	2.47			6.70	0.26	
Stop (OB)	2.48					
Stop (IB)	2.72					
Tangent (at 40th Ave.)	2.73					0.06
Grade	2.79			6.50	0.26	
Stop (OB)	2.80					
Stop (IB)	3.04					

Section 1: From La Playa to 9th Ave. (continued)

Point of Change	Distance From Start	Curve Radius	Curve Length	Grade % (+ or -)	Grade Length	Tangent Length
Tangent (at 39th Ave.)	3.05					0.06
Grade	3.11			6.50	0.25	
Stop (OB)	3.12					
Stop (IB)	3.35					
Tangent (at 38th Ave.)	3.36					0.06
Grade	3.43			0.80	0.26	
Stop (OB)	3.44					
Stop (IB)	3.68					
Tangent (at 37th Ave.)	3.69					0.05
Grade	3.74			6.20	0.26	
Stop (OB)	3.75					
Stop (IB)	3.99					
Tangent (at 36th Ave.)	4.00					0.07
Grade	4.07			6.20	0.26	
Stop (OB)	4.08					
Stop (IB)	4.32					
Tangent (at 35th Ave.)	4.33					0.04
Grade	4.37			6.20	0.29	
Tangent (at 34th Ave.)	4.66					0.06
Grade	4.72			6.20	0.26	
Stop (OB)	4.71					
Stop (IB)	4.97					
Tangent (at 33rd Ave.)	4.98					0.05
Grade	5.03			-0.80	0.24	
Tangent (at 32nd Ave.)	5.27					0.05
Grade	5.32			-2.10	0.27	
Stop (OB)	5.33					
Stop (IB)	5.58					
Tangent (at 31st Ave.)	5.59					0.05
Grade	5.64			-4.10	0.27	
Stop (OB)	5.65					
Stop (IB)	5.90					
Tangent (at 30th Ave.)	5.91					0.05
Grade	5.96			1.20	0.26	
Stop (OB)	5.97					
Stop (IB)	6.21					
Tangent (at 29th Ave.)	6.22					0.06
Grade	6.28			2.90	0.23	
Tangent (at 28th Ave.)	6.51					0.05
Grade	6.56			3.60	0.25	
Stop (OB)	6.57					
Stop (IB)	6.80					
Tangent (at 27th Ave.)	6.81					0.04
Grade	6.85			0.80	0.26	
Crossover	6.94					

"N" - Judah Line

Section 1: From La Playa to 9th Ave. (continued)

Point of Change	Distance From Start	Curve Radius	Curve Length	Grade % (+ or -)	Grade Length	Tangent Length
Tangent (at 26th Ave.)	7.11					0.07
Grade	7.18			-5.00	0.26	
Stop (OB)	7.19					
Stop (IB)	7.43					
Tangent (at 25th Ave.)	7.44					0.06
Grade	7.50			-2.50	0.25	
Tangent (at 24th Ave.)	7.75					0.06
Grade	7.81			4.60	0.25	
Stop (OB)	7.82					
Stop (IB)	8.06					
Tangent (at 23rd Ave.)	8.06					0.07
Stop (OB)	8.06					
Grade	8.13			7.80	0.24	
Stop (IB)	8.36					
Tangent (at 22nd Ave.)	8.37					0.06
Grade	8.43			1.20	0.25	
Stop (OB)	8.44					
Tangent (at 21st Ave.)	8.68					0.05
Grade	8.73			2.50	0.26	
Tangent (at 20th Ave.)	8.99					0.05
Grade	9.04			4.70	0.26	
Stop (OB)	9.05					
Stop (IB)	9.29					
Tangent (at 19th Ave.)	9.30					0.05
Grade	9.35			-2.80	0.25	
Stop (OB)	9.59					
Tangent (at 18th Ave.)	9.60					0.06
Grade	9.66			5.40	0.25	
Stop (OB)	9.67					
Stop (IB)	9.90					
Tangent (at 17th Ave.)	9.91					0.06
Grade	9.97			7.10	0.26	
Tangent (at 16th Ave.)	10.23					0.06
Grade	10.29			7.80	0.26	
Stop (OB)	10.53					
Tangent (at 15th Ave.)	10.54					0.05
Grade	10.59			-5.10	0.25	
Tangent (at 14th Ave.)	10.84					0.05
Grade	10.89			5.00	0.27	
Stop (OB)	10.90					
Stop (IB)	11.15					
Tangent (at 13th Ave.)	11.16					0.06
Grade	11.22			4.20	0.24	
Tangent (at 12th Ave.)	11.46					0.08
Grade	11.54			0.40	0.27	

"N" - Judah Line

Section 1: From La Playa to 9th Ave. (continued)

Point of Change	Distance From Start	Curve Radius	Curve Length	Grade % (+ or -)	Grade Length	Tangent Length
Stop (OB)	11.55					
Stop (IB)	11.80					
Tangent (at 11th Ave.)	11.81					0.05
Grade	11.86			1.70	0.27	
Tangent (at 10th Ave.)	12.13					0.05
Grade	12.18			2.10	0.29	
Stop (OB)	12.19					
Curve (at 9th and Irving)	12.44	42' - 7.5"	0.03			
Stop (IB)	12.46					
Stop (OB)	12.46					
End (Section 1)	12.47					

Lenght of Section 1: 12,470 Ft.
Tangent Length: 2,280 Ft.
Grade Length: 10,190 Ft.

"N" - Judah Line

Section 2: 9th Ave. from Judah St. to Irving St.

Point of Change	Distance From Start	Curve Radius	Curve Length	Grade % (+ or -)	Grade Length	Tangent Length
Curve (left)	12.47	42' - 7.5"	0.07			
Tangent (at 9th Ave.)	12.47					0.07
Grade	12.54			-4.00	0.56	
Tangent (9th Ave.)	13.10					0.07
Curve (right)	13.10	42' - 7.5"	0.07			
End (Section 2)	13.17					

Lenght of Section 2: 700Ft.
Tangent Length: 140 Ft.
Grade Length: 560 Ft.

"N" - Judah Line

Section 3: Irving Street from 9th Ave. to Arguello Blvd.

Point of Change	Distance From Start	Curve Radius	Curve Length	Grade % (+ or -)	Grade Length	Tangent Length
Curve	13.17	42' - 7.5°	0.04			
Grade	13.17			5.00	0.28	
Stop (IB)	13.18					
Stop (OB)	13.18					
Tangent (at 8th Ave.)	13.45					0.08
Grade	13.53			2.90	0.22	
Stop (IB)	13.74					
Tangent (at 7th Ave.)	13.75					0.06
Grade	13.81			0.40	0.27	
Stop (OB)	13.82					
Tangent (at 6th Ave.)	14.08					0.05
Grade	14.13			0.40	0.23	
Stop (OB)	14.14					
Stop (IB)	14.35					
Tangent (at 5th Ave.)	14.36					0.05
Grade	14.41			0.40	0.27	
Tangent (at 4th Ave.)	14.68					0.04
Grade	14.72			3.80	0.28	
Stop (OB)	14.73					
Stop (IB)	14.99					
Tangent (at 3rd Ave.)	15					0.04
Grade	15.04			5.40	0.27	
Tangent (at 2nd Ave.)	15.31					0.05
Stop (OB)	15.33					
Grade	15.36			4.90	0.15	
Curve (left)	15.5	42' - 7.5°	0.01			
End (Section 3)	15.51					

Length of Section 3: 2,340 Ft.
Tangent Length: 370 Ft.
Grade Length: 2,010 Ft.

"N" - Judah Line

Section 4: Arguello Blvd. from Irving St. to Carl St.

Point of Change	Distance From Start	Curve Radius	Curve Length	Grade % (+ or -)	Grade Length	Tangent Length
Curve (left)	15.51	42' - 7.5°	0.09			
Grade	15.51			-4.30	0.26	
Curve (right)	15.69	42' - 7.5°	0.08			
Stop (OB, Arguello\Irving)	15.77					
End (Section 4)	15.77					

Length of Section 4: 260 Ft.
Tangent Length: 0
Grade Length: 260 Ft.

"N" - Judah Line

Section 5: Carl St. from Arguello Blvd. to Sunset Tunnel

Point of Change	Distance From Start	Curve Radius	Curve Length	Grade % (+ or -)	Grade Length	Tangent Length
Grade	15.77			1.20	0.61	
Stop (IB, at Hillway Ave.)	15.91					
Grade	16.38			-1.80	0.25	
Stop (IB)	16.62					
Tangent (at Willard)	16.63					0.06
Grade	16.69			-3.40	0.43	
Stop (OB)	16.7					
Stop (IB)	17.11					
Tangent (at Stanyan)	17.12					0.06
Grade	17.18			3.20	0.33	
Stop (OB)	17.19					
Tangent	17.51					0.08
Grade	17.59			-5.90	0.28	
Stop (IB)	17.86					
Tangent (at Cole)	17.87					0.06
Grade	17.93			-3.20	0.17	
Stop (OB)	17.94					
Curve (right)	18.08	50 Ft.	0.06			
Grade	18.1			-4.00	0.26	
Stop (IB, at Belvedere St.)	18.23					
Stop (OB, at Belvedere St.)	18.23					
Curve (left)	18.23	250 Ft.	0.13			
End (Section 5)	18.36					

Length of Section 5: 2,590 Ft.
Tangent Length: 260 Ft.
Grade Length: 2,330 Ft.

"N" - Judah Line

Section 6: Sunset Tunnel

Point of Change	Distance From Start	Curve Radius	Curve Length	Grade % (+ or -)	Grade Length	Tangent Length
West Portal, Sunset Tunnel	18.36					
Grade	18.36			-4.00	0.20	
Grade	18.56			-3.00	3.03	
Grade	21.59			-3.20	0.27	
Tangent	21.86					0.07
Grade	21.93			-3.00	0.67	
Curve	22.44	511 Ft.	0.10			
East Portal, Sunset Tunnel	22.6					

Lenght of Section 6: 4,240 ft.
Tangent Length: 70 Ft.
Grade Length: 4,170 Ft.

"N" - Judah Line

Section 7: Duboce Ave. from Sunset Tunnel to Market Street Subway

Point of Change	Distance From Start	Curve Radius	Curve Length	Grade % (+ or -)	Grade Length	Tangent Length
Tanget (at Noe St.)	22.60					0.20
Stop (IB at Pierce St.)	22.73					
Stop (OB at Pierce St.)	22.73					
Tangent (at Walter St.)	22.80					0.06
Curve (left)	22.86	200 Ft.	0.10			
Grade	22.88			-4.90	0.55	
Curve (right)	22.96	200 Ft.	0.10			
Stop (IB)	23.42					
Tangent (at Sanchez St.)	23.43					0.07
Grade	23.50			-2.10	0.53	
Stop (OB)	23.51					
Stop (IB)	24.02					
Tangent (at Church St.)	24.03					0.10
Turn Off (J Line)	24.03					
Grade	24.13			-0.80	0.03	
Stop (OB)	24.14					
Grade (OB)	24.16			-0.80	0.20	
Grade (IB)	24.16			-3.83	0.30	
Grade (OB)	24.36			-8.07	0.32	
Grade (IB)	24.46			-8.09	0.22	
Grade (OB)	24.68			-4.94	0.29	
Grade (IB)	24.68			-5.70	0.32	
Portal (Market Street Subway)	24.70					
Curve (right)	24.96	400 Ft.	0.27	-1.80	0.16	
Grade (OB)	24.97			-0.81	0.22	
Grade (IB)	25.00					
End of N Line	25.22					

Length of Section 7: 2,620 Ft. (double track)
950 Ft. (single track WB)
1,060 Ft. (single track EB)

Tangent Length: 450 Ft.

Grade Length: 23,710 Ft. (double track)
950 Ft. (single track WB)
1,060 Ft. (single track EB)

SUMMARY

"N" - Judah Line

Total Length of N line:	24,160 Ft. (double track)			
	2,030 Ft. (single track)			
Tangent Length:	3,570 Ft.			
Grade Length:	20,590 Ft. (double track)		**Double**	**Single**
	2,030 Ft. (single track)	up 1%	1,830 Ft.	420 Ft.
		1% to 2%	1,640 Ft.	160 Ft.
		2% to 3%	2,300 Ft.	0 Ft.
		3% to 4%	6,650 Ft.	300 Ft.
		4% to 5%	3,250 Ft.	290 Ft.
		5% to 6%	2,090 Ft.	320 Ft.
		6% to 7%	2,070 Ft.	0 Ft.
		7% to 8%	760 Ft.	0 Ft.
		8% up	0 Ft.	540 Ft.
Curve Length: 1,250 Ft.	Radius	0' - 100'	550 Ft.	
	Radius	100' - 500'	600 Ft.	
		500' up	100 Ft.	
Number of Stops (Out Bound): 40		Min Distance		250 Ft.
		Max Distance		1,219 Ft.
		Avr Distance		520 Ft. (w/o tunnel)
Number of Stops (In Bound): 44		Min Distance		238 Ft.
		Max Distance		900 Ft.
		Avr Distance		477 Ft.

Market St. Subway: J,K, L M & N Lines

Section 1: From East Portal to Embarcadero Track End

Distance in 1000's of Feet

Point of Change	Distance From Start	Curve Radius	Curve Length	Grade % (+ or -)	Grade Length	Tangent Length	Station Length	Distance Length	Trans. Length
Curve (right)	0.00	1,000'	0.10						
Grade	0.00			-5.00	0.10				
Curve (right)	0.10	2,500'	0.58						
Grade	0.10			-1.00	4.00				
Castro St. Station	0.10						0.40		
Grade	0.50			-1.63	0.94				
Grade	1.44			-5.00	0.94				
Church St. Station	2.38						0.40		
Grade	2.38			-1.00	0.50				
Grade (IB)	2.88			-1.00	0.13				
Grade (OB)	2.88			5.00	0.52				
Grade (IB)	3.01			1.23	0.32				
13' dist between tracks	3.21							2.70	
Grade (IB)	3.33			1.00	0.17				
Grade (OB)	3.40			4.83	0.10				
Grade (IB)	3.50			0.75	0.11				
Grade (OB)	3.50			3.64	0.11				
Track Transition	3.54								0.26
Grade (IB)	3.61			0.05	0.39				
Grade (OB)	3.61			2.28	0.09				
Grade (OB)	3.70			0.92	0.11				
Grade (OB)	3.81			0.44	0.09				
Grade (OB)	3.90			-1.68	0.10				
Grade (OB)	4.00			-1.80	0.11				
Grade (IB)	4.00			-0.20	0.31				
Grade (OB)	4.11			-2.00	0.12				
Turn Off (J&N Lines)	4.21								
Grade (OB)	4.23			-3.40	0.08				
Grade (OB)	4.31			-4.80	0.10				
Grade (IB)	4.31			-0.35	0.09				
Grade (IB)	4.40			-1.40	0.10				
Grade (OB)	4.41			-5.00	0.50				
Grade (IB)	4.50			-2.60	0.10				
Grade (IB)	4.60			-3.80	0.11				
Grade (IB)	4.71			-4.83	0.10				
Grade (IB)	4.81			-5.00	0.10				
Grade	4.91			-5.00	0.20				
Grade	5.11			-4.71	0.10				
Grade	5.21			-3.71	0.10				
Grade	5.31			-2.69	0.10				
Grade	5.41			-1.69	0.09				
Grade	5.50			-1.40	0.89				
17' dist between tracks	5.91							0.75	
Crossover (double)	6.00								
Track Transition	6.20								0.30

Market St. Subway: J,K, L M & N Lines

Section 1: From East Portal to Embarcadero Track End (continued)

Point of Change	Distance From Start	Curve Radius	Curve Length	Grade % (+ or -)	Grade Length	Tangent Length	Station Length	Distance Length	Trans. Length
3rd Track	6.25								
Grade	6.39			-0.90	0.11				
Grade	6.50			-0.30	0.50				
Van Ness Station	6.59						0.38		
32' dist between tracks	6.66							1.97	
Grade	7.00			-4.00	0.11				
Grade	7.11			-0.70	0.10				
Grade	7.21			-0.30	0.29				
Grade	7.50			-0.30	0.88				
Track Transition	8.01								0.40
Grade	8.38			-0.65	0.12				
Grade	8.50			-1.00	1.00				
44' dist between tracks	8.63							5.70	
Civic Center Station	8.68						0.71		
Grade	9.50			-0.68	0.10				
Grade	9.60			-0.45	0.10				
Grade	9.70			-0.03	1.30				
Grade	11.00			0.14	0.10				
Grade	11.10			0.19	0.13				
Grade	11.23			0.53	0.08				
Powell St. Station	11.28						0.80		
Grade	11.31			0.70	0.79				
Grade	12.10			0.52	0.11				
Grade	12.21			0.49	0.10				
Grade	12.31			0.16	0.09				
Grade	12.40			-0.18	0.10				
Grade	12.50			-0.53	0.11				
Grade	12.61			-0.80	0.39				
Montgomery St. Station	13.61						0.77		
44' dist between tracks	14.33							0.67	
Track Transition	14.60								0.40
Grade	15.00			-1.00	0.16				
44' dist between tracks	15.00							1.12	
34' DIST	15.12							1.15	
Grade	15.16			-0.60	1.11				
Crossover (double)	15.19								
Embarcadero Station	15.59					0.68			
End of track	16.27								

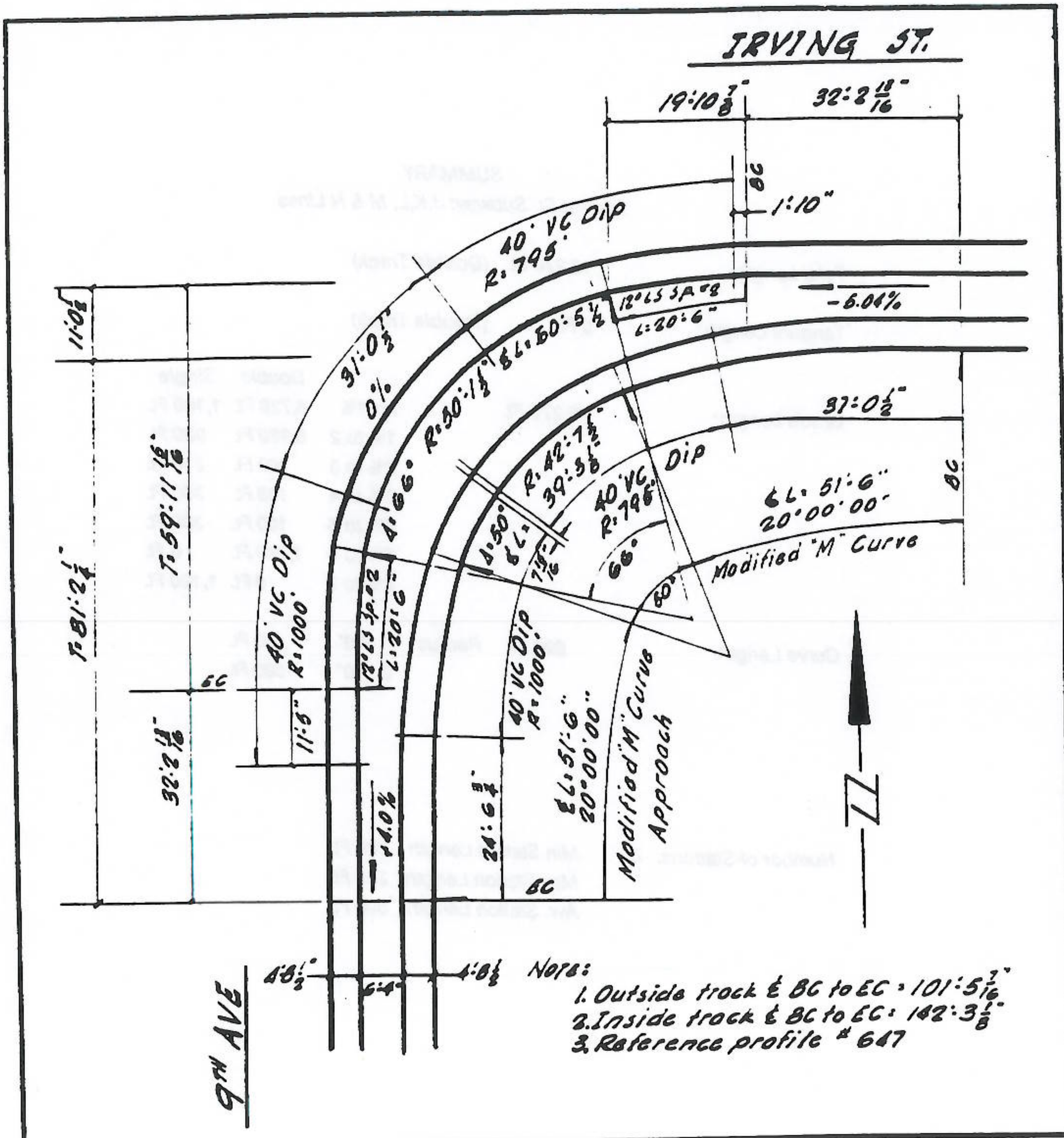
Length of Section : 16,270 Ft.
Tangent Length: 0
Grade Length: 16,270 Ft.

SUMMARY

Market St. Subway: J,K,L, M & N Lines

Total Length:	16,270 Ft.	(Double Track)			
Tangent Length:	0 Ft.	(Double Track)			
				Double	Single
Grade Length:	16,270 Ft.		up 1%	6,720 Ft.	1,100 Ft.
			1% to 2	5,980 Ft.	930 Ft.
			2% to 3	100 Ft.	310 Ft.
			3% to 4	100 Ft.	300 Ft.
			4% to 5	100 Ft.	300 Ft.
			5% to 6	1,240 Ft.	0 Ft.
			6% to 7	0 Ft.	1,120 Ft.
Curve Length:	690 Ft.	Radius	1,000'	100 Ft.	
			2,500'	580 Ft.	

Number of Stations: 7	Min Station Length	800 Ft.
	Max Station Length	380 Ft.
	Avr. Station Length	590 Ft.



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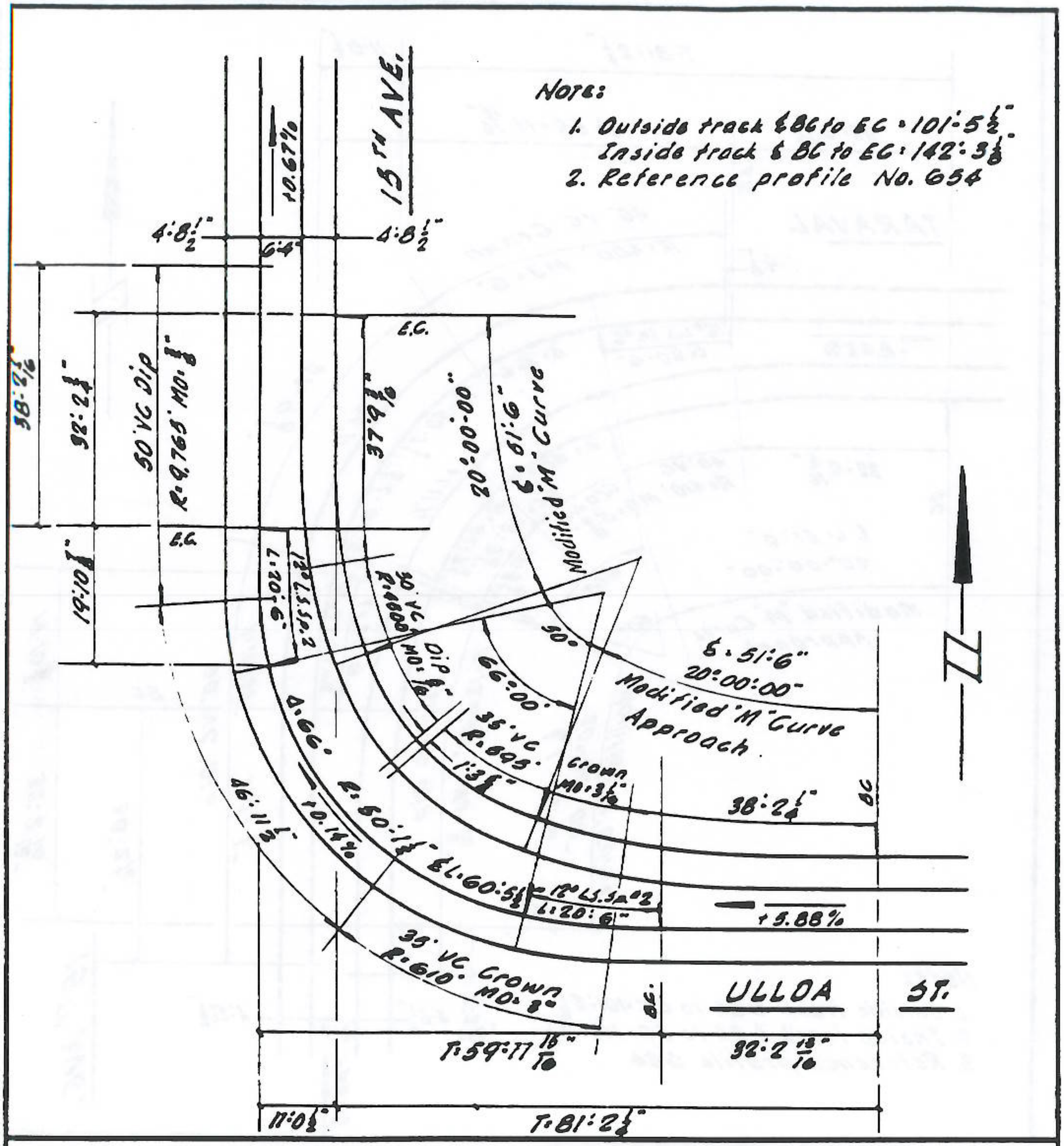
UTILITIES ENGINEERING BUREAU

MUNICIPAL RAILWAY

IRVING STREET & 9TH AVENUE
VERTICAL & HORIZONTAL CURVES

BY ASE	TR.	APPROVED	SCALE 1"=20'	DATE 3-68 / LATEST REVISION
DR. WH	CH. A.S.E.	APPROVED		DRAWING NO. AL-2627 / REVISION NO. 0
RECOMMENDED		GENERAL MANAGER		



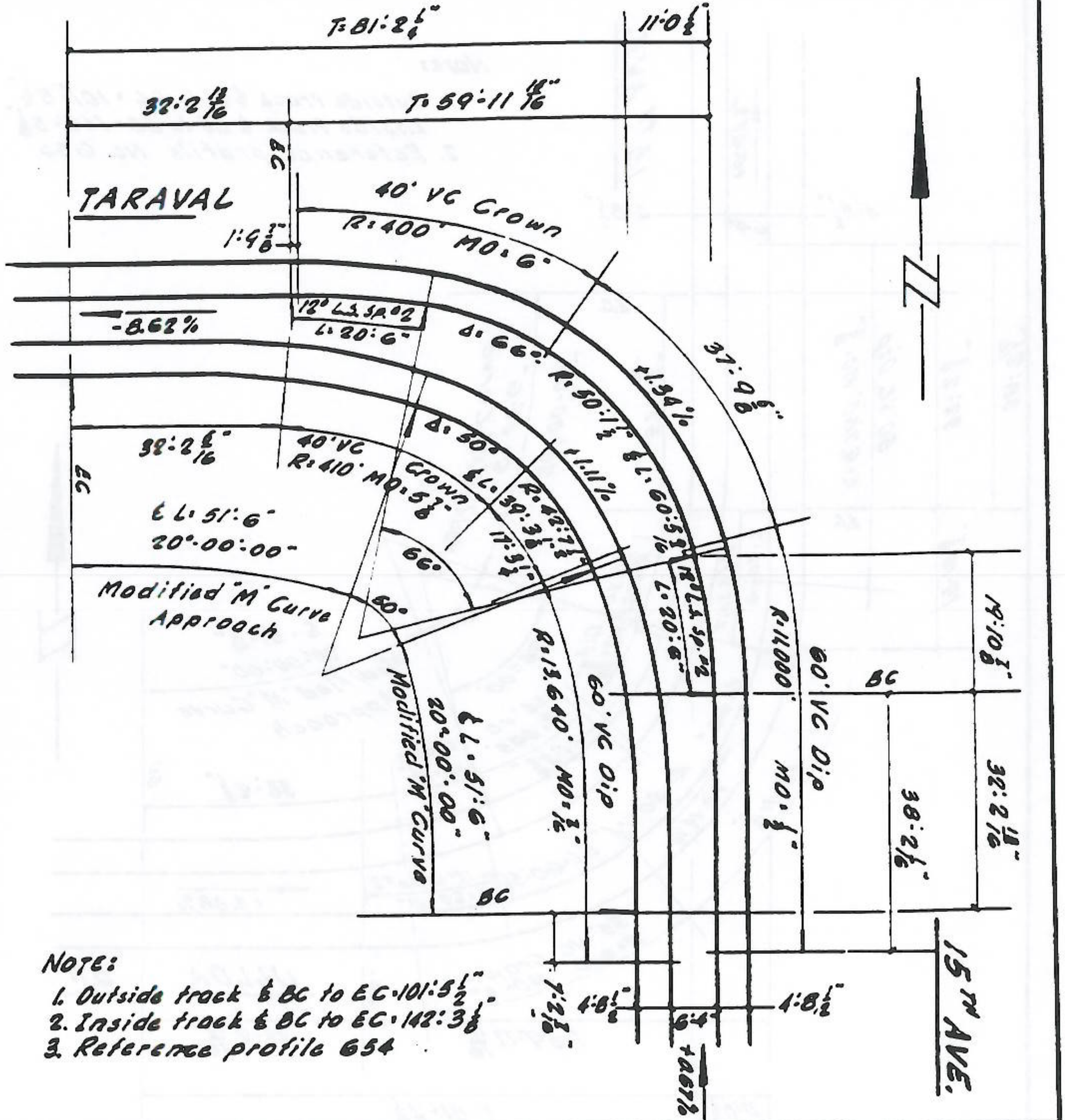
CITY AND COUNTY OF SAN FRANCISCO — PUBLIC UTILITIES COMMISSION

UTILITIES ENGINEERING BUREAU

MUNICIPAL RAILWAY

ULLOA STREET & 15TH AVENUE
VERTICAL & HORIZONTAL CURVES

BY ASE	TR.	APPROVED	SCALE 1"=20'	DATE 3-68	LATEST REVISION	
DR. WH	CH. A.S.E.	APPROVED		DRAWING NO. AL-2628		REVISION NO. 0
RECOMMENDED		GENERAL MANAGER				



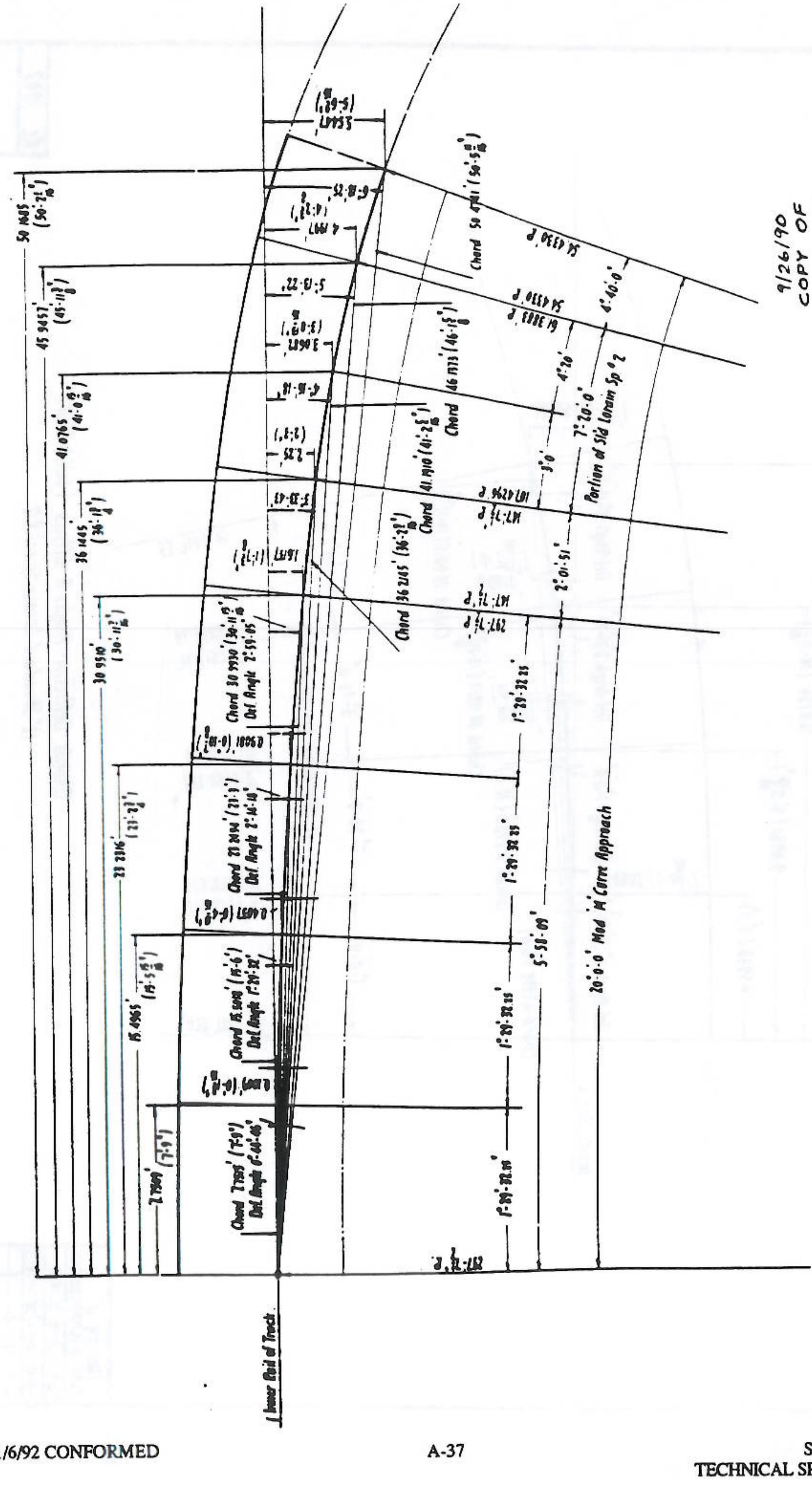
CITY AND COUNTY OF SAN FRANCISCO — PUBLIC UTILITIES COMMISSION

UTILITIES ENGINEERING BUREAU

MUNICIPAL RAILWAY

15TH AVENUE & TARAVAL STREET
VERTICAL & HORIZONTAL CURVES

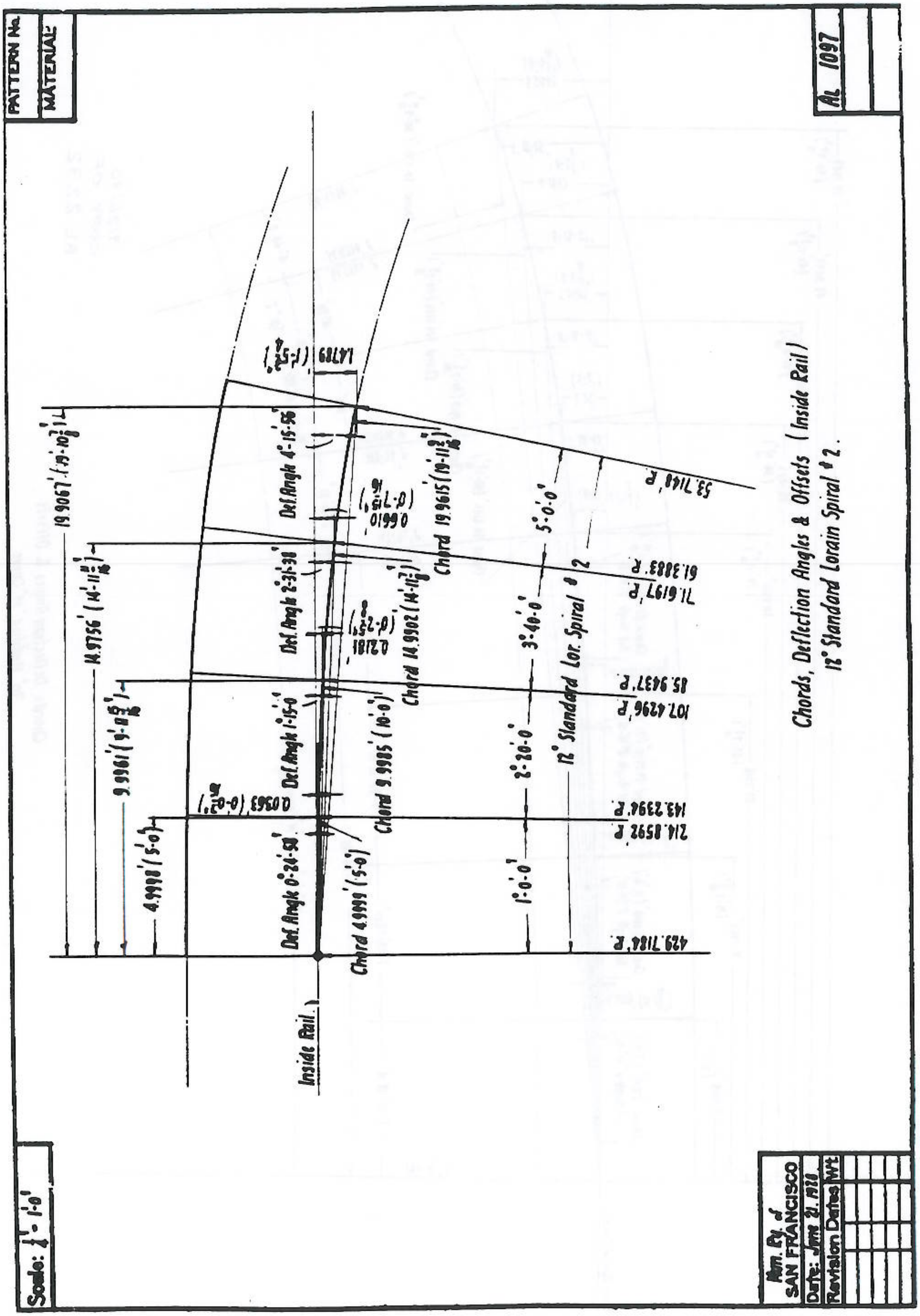
BY ASE	TR.	APPROVED	SCALE 1"=20'	DATE 5-68	LATEST REVISION
WH	CH. A.S.E.	APPROVED		DRAWING NO. AL-2629	REVISION NO. 0
RECOMMENDED		GENERAL MANAGER			



9/26/90
COPY OF
BL 2232

Chords, Deflection Angles & Offsets
20° Modified 'M' Curve

Scale 1/4" = 1'-0"



PATTERN No.
MATERIAL
AL 1097
Scale: 1/4" = 1'-0"
Mun. Ry. of SAN FRANCISCO
Date: June 21, 1928
Revision Dates
Wt.
Chords, Deflection Angles & Offsets (Inside Rail)
12° Standard Lorain Spiral # 2.
12° Standard Lor. Spiral # 2
Inside Rail
429.7184' R
214.8592' R
143.2394' R
107.4296' R
85.9437' R
71.6197' R
61.3883' R
53.7148' R
1°-0'-0"
2°-20'-0"
3°-40'-0"
5°-0'-0"
Del. Angle 0°-24'-58"
Del. Angle 1°-15'-0"
Del. Angle 2°-31'-38"
Del. Angle 4°-15'-56"
Chord 4.9999' (5'-0")
Chord 9.9985' (10'-0")
Chord 14.9902' (14'-11 7/8")
Chord 19.9615' (19'-11 9/16")
4.9998' (5'-0")
9.9961' (9'-11 15/16")
14.9756' (14'-11 11/16")
19.9067' (19'-10 7/8")
0.0563' (0'-0 11/16")
0.2181' (0'-2 5/8")
0.6610' (0'-7 15/16")
1.4789' (1'-5 3/4")

4. ATCS LRV2 On-Board Equipment

MUNI ATCS LRV2 ON-BOARD EQUIPMENT

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Figure 29 Train ID Unit	15
Figure 30 Driver Display Unit	16
Figure 31 Disconnect Unit	17
Figure 32 Destination Sign Interface Box	18
Figure 33 Digital Voice Announcement System	19

1. EQUIPMENT DESCRIPTION

This section provides physical descriptions of the LRV2 On-Board Equipment in the MUNI ATCS. The On-Board Equipment consists of the following:

- Rack mounted equipment:
  - -Power Supply Unit;
  - -Electronics Unit (EU);
  - -Communications Unit (CU);
  - -Interface Relay Unit (IRU); and
  - -P.Signal Generator.

- Peripheral Equipment:
  - -Two Tachometers;
  - -Two Receive Antennas;
  - -Two Transmit Antennas;
  - -Accelerometer (mounted to VOBC Rack);
  - -Two Driver's Control Boxes;
  - -Two Train ID Units;
  - -Two Driver Display Units;
  - -Two Disconnect Units;
  - -Destination Sign Interface Box; and
  - -Digital Voice Announcement.

- Cable Set.

Figure 4 shows the location of the On-Board Equipment in the LRV2 vehicle.

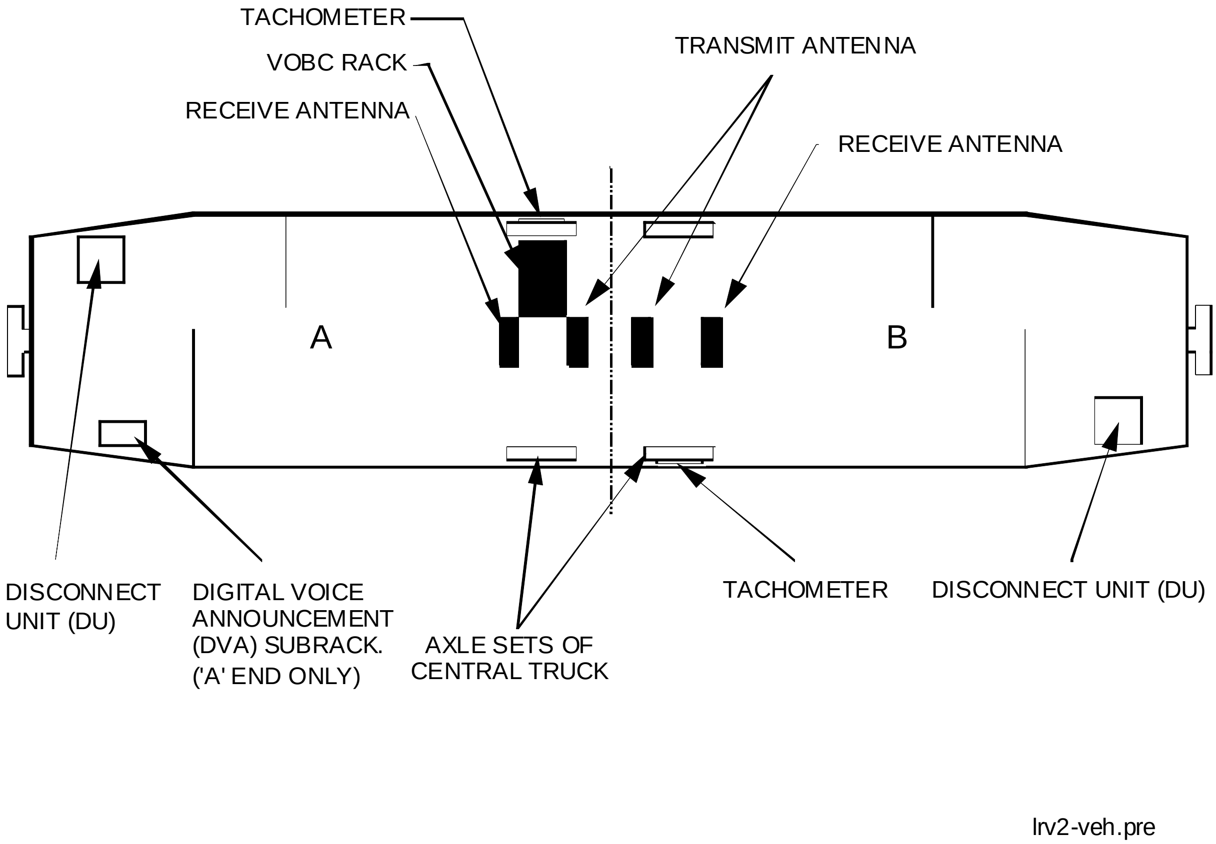


Figure 1 LRV2 On-Board Equipment Location

1.1 LRV2 VOBC Assembly

The LRV2 VOBC Rack is shown in Figure 5 and consists of the following equipment:

Item	Description	ATA Part Number
1	Power Supply Unit (PSU)	300-2-00157-AAB
2	Electronics Unit (EU)	3CU 10001 ABAA
3	Interface Relay Unit (IRU)	3CU 10002 ABAA
4	Communications Unit (CU)	3CU 10027 ABAA
5	P. Signal Generator	300-3-00232

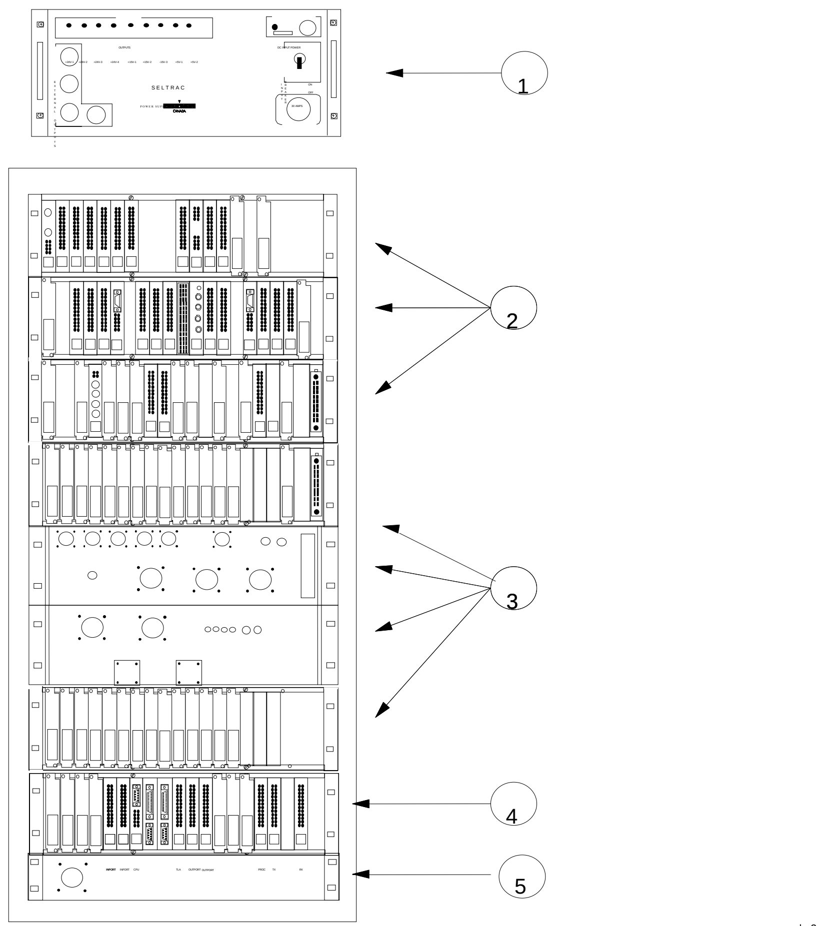


Figure 2 LRV2 VOBC AssemblyNote:

The PSU (Item 1) is housed under the back-to-back seats and is connected to the rack housing (items 2, 3 and 4) by cable. The LRV2 On-Board Equipment location is shown in Figure 4.

1.1.1 Power Supply Unit — 300-2-00157-AAB

Item	Description	ATA Part Number
1	Power Supply Assembly 1	401-2-00323-AAC
2	Power Supply Assembly 2	401-2-00323-AAC
3	Power Supply Assembly 3	401-2-00324-AAB
4	Over Voltage Board Assembly	401-2-00327
5	Metal Oxide Varistor	601-3-00171
6	PBA LED Mount (p/o 403-2-00202 Cable Assy PSU)	401-2-00326

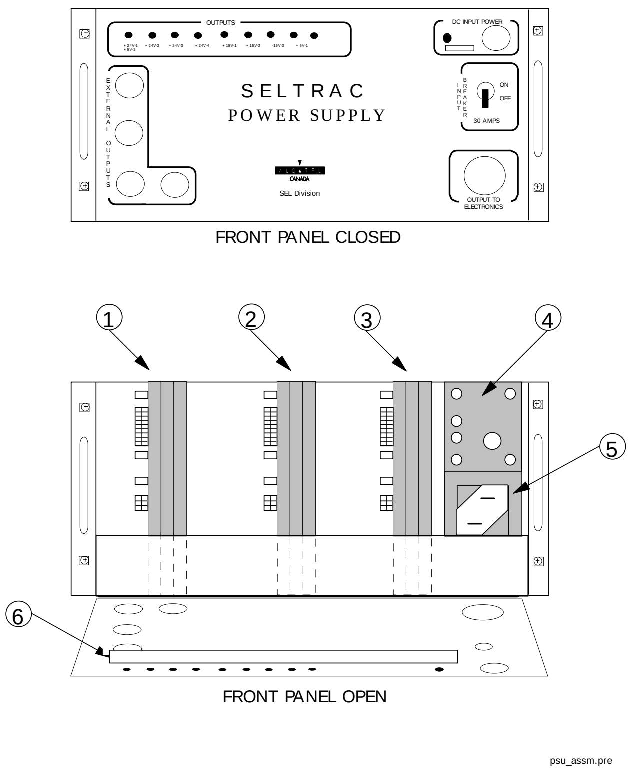


Figure 3 LRV2 VOBC Rack Power Supply Unit

1.1.2 Electronics Unit **3CU 10001 ABAA**

The EU, shown in Figure 7, is the vital controller of the VOBC. The EU is responsible for monitoring all on-board status signals, the control of vehicle subsystem, the processing of incoming VCC telegrams and the generation of VOBC response telegrams.

The EU subrack, P/N 400-2-00185 AAC, houses the following modules:

Item	Description	ATA Part Number
1	Antenna Filter	58222-03320
2	High Frequency Receiver A	58222-03270
3	High Frequency Receiver B	58222-06850
4	High Frequency Receiver C	58222-03290
5	High Frequency Receiver D	58222-03301
6	Digital Receiver A	58222-04590
7	Digital Receiver B	58222-06860
8	Data Transmitter	58222-06880
9	High Frequency Transmitter A	58222-03240
10	High Frequency Transmitter B	58222-03250
11	High Frequency Transmitter C	58222-08660
12	Positioning Computer (TWR)	401-2-00356-AAC
13	Computer Input	401-2-00167
14	Central Processing Unit	3CU 10035 AFAA
15	Temporary Latch 'A'	401-2-00163-AAA
16	Output Port	401-2-00170
17	Interrupt Controller	401-2-00221-AAE
18	Vehicle Identity	401-2-00341-AAB
19	Vehicle Identity Plug In	300-2-00172-XXX*****
20	Force Actuated Relay	3CU 20015 AFAA
21	Output Relays 'A'	3CU 20053 AAAB
22	D/A Isolation Amplifier	3CU 20000 AAAA
23	Interval Measurement Control	401-2-00176
24	Input	401-2-00168
25	Power I/P Connector	N/A
26	Transmitter/Receiver (T/R)	401-2-00368-AAD

The '*' in Item 19 indicates that there are multiple variants used for the Vehicle Identity Plug In.

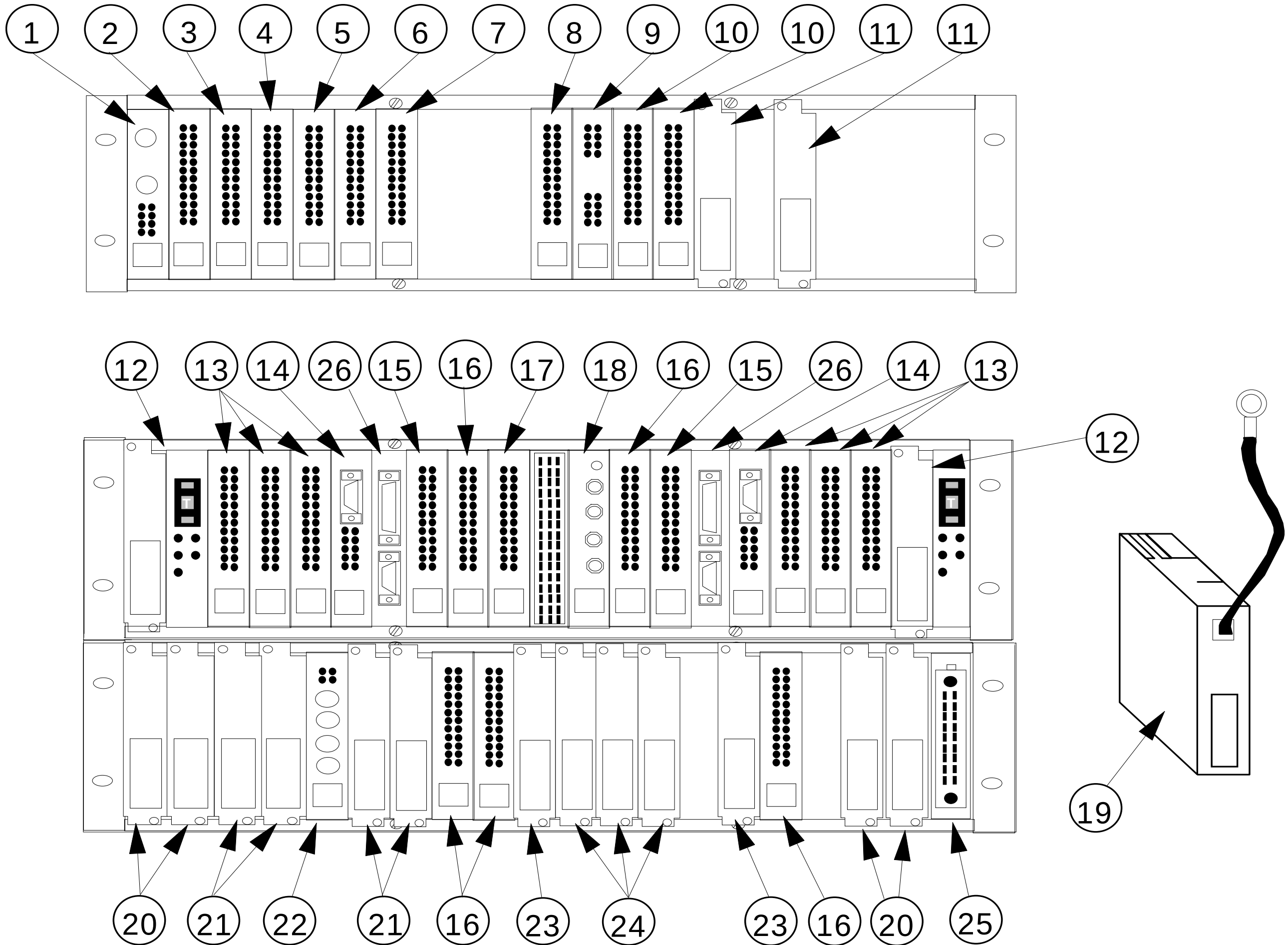


Figure 4   VOBC Rack Electronics Unit

1.1.3 Interface Relay Unit 3CU 10002 ABAA

The Interface Relay Unit (IRU) is responsible for the following:

- Train integrity function;
- Selection of common train power in the vehicle with an active VOBC in AUTO mode; and
- Emergency Brake control in AUTO and Cab Signal modes.

The IRU is shown in Figure 8 and consists of the following:

Item	Description	ATA Part Number
1	Latching Relay 4 Pole Double Throw	400-3-00328
2	Power Relay	400-3-00008
3	Relay 4 Pole Double Throw	400-3-00329
4	Cable Connector	401-2-00342-AAA
5	Cable Connector	401-2-00342-AAN
6	Trainline Filter Board	401-2-00339-AAM
7	Trainline Filter Board	401-2-00339-AAN
8	Trainline Filter Board	401-2-00339-AAP
9	Trainline Filter Board	401-2-00339-AAQ
10	Trainline Filter Board	401-2-00339-AAR
11	Trainline Filter Board	401-2-00339-AAU
12	Trainline Filter Board	401-2-00339-AAY

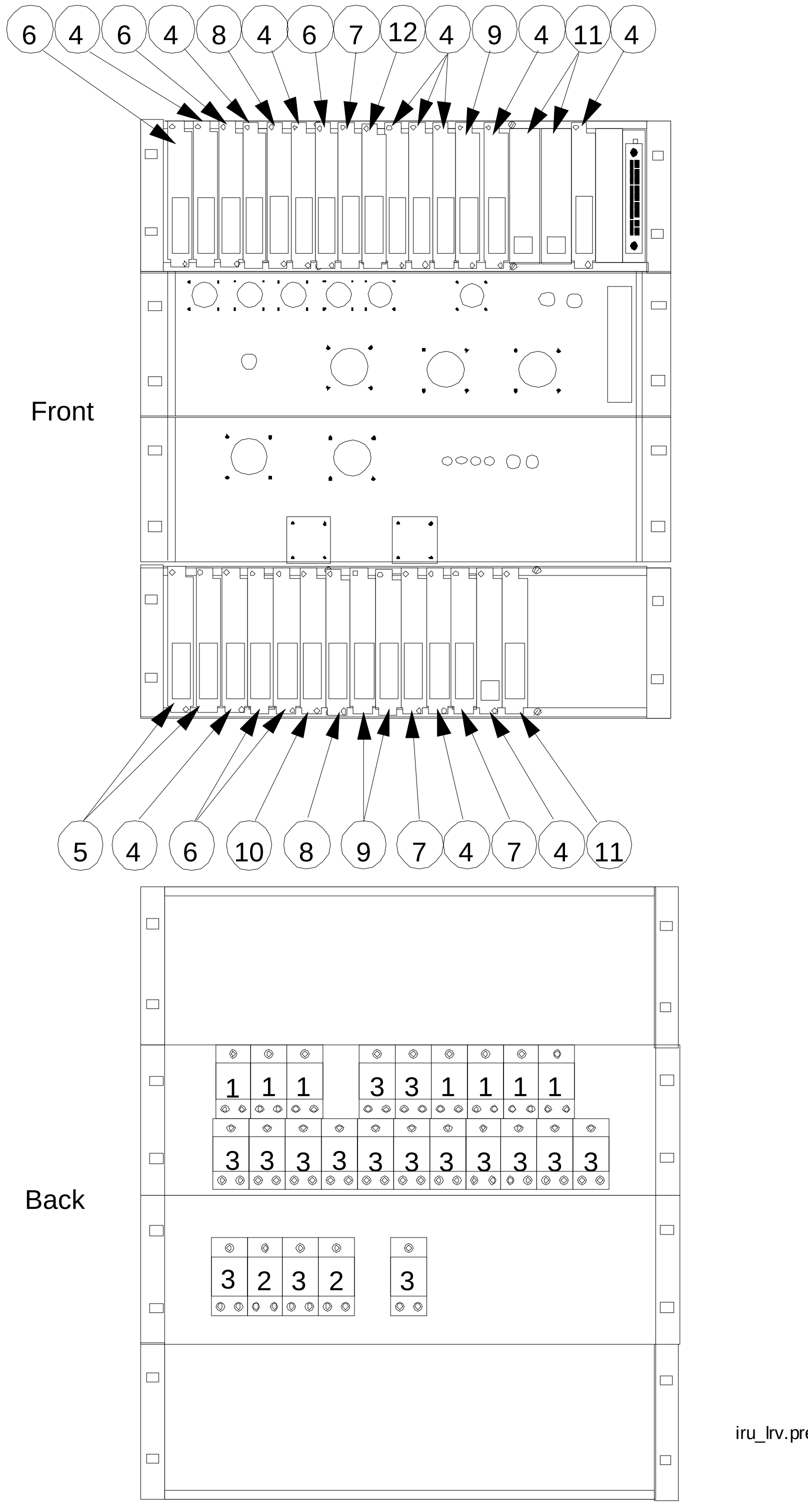


Figure 5 Interface Relay Unit

1.1.4 Communication Unit 3CU 10027 ABAA

Communications between the train EUs, passenger information equipment and train-end equipment is a function of the Communications Unit (CU). The CU is shown in Figure 9 and consists of the following:

Item	Description	ATA Part Number
1	Input Card	401-2-00264-BAJ
2	Computer Input Card (Inport)	401-2-00167
3	CPU Card	3CU 10035 AAAA
4	TX/RX Card	401-2-00368-AAK
5	TX/RX Card	401-2-00368-AAN
6	TLA Card	401-2-00163-AAB
7	Output Port Card (Outport)	401-2-00170
8	Output Relays	3CU 20053 AAAB
9	CU Processor	3CU 10036 ABAA
10	Transmitter Card	401-2-00318-AAC
11	Receiver Card	401-2-00320-AAD
12	DC/DC Converter (backplane mounted)	400-3-00493

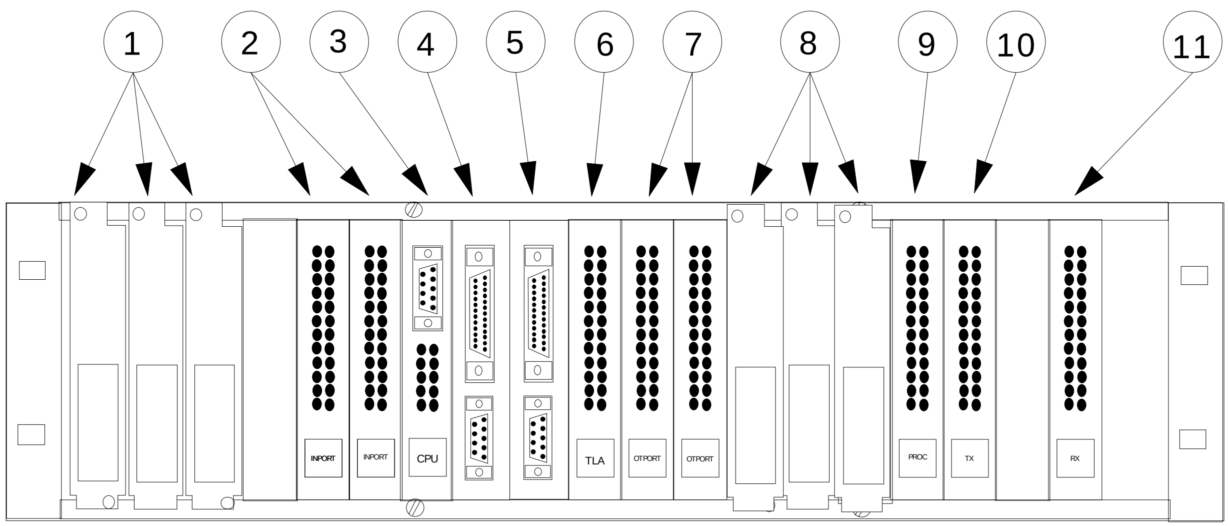


Figure 6 Communications Unit

1.1.5 P. Signal Generator 300-3-00232

The P. Signal Generator converts the 0-10 volt analog output from the D/A Isolation Amplifier in the EU to a current signal compatible with the propulsion system interface. It is located in the bottom position in the VOBC Rack. Refer to Figure 23.

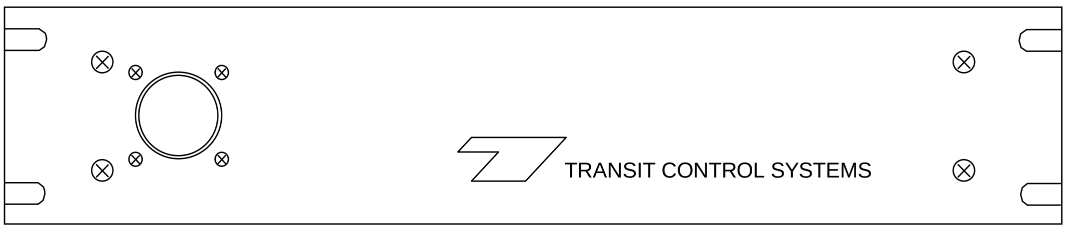


Figure 7 P. Signal Generator

1.2 VOBC Peripheral Equipment

1.2.1 Tachometer **300-3-00208**

The four-channel Tachometer is shown in Figure 24. One Tachometer is mounted on each of the center truck axles on opposite sides of the vehicle.

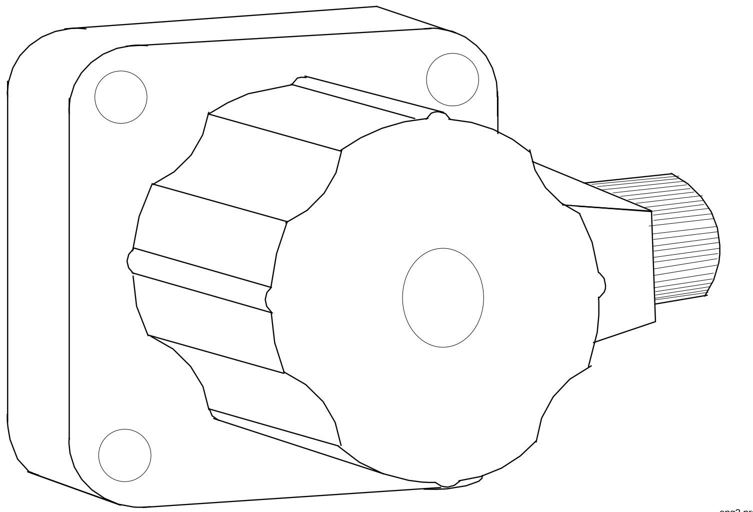


Figure 8 Tachometer

.

Figure 9 Tachometer 1 and 2 Output Signals

1.2.2 Antennas Receive 300-2-00120-AAC

Figure 26 shows the transmit/receive Antenna. There are two transmit and two receive Antennas on each vehicle mounted on the center truck.

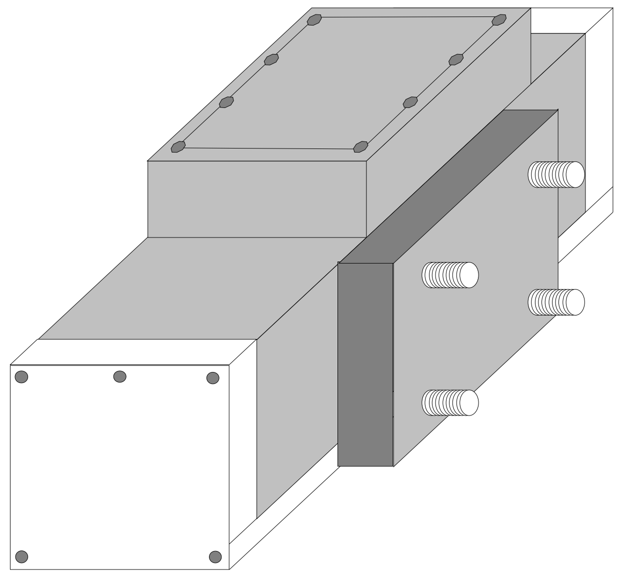


Figure 10 Loop Communications Antennas

1.2.3 Accelerometer Assembly **3CU 10037 AAAA**

The Accelerometer Assembly is shown below. It is mounted in the Electronics Rack on a level adjustment plate. It.

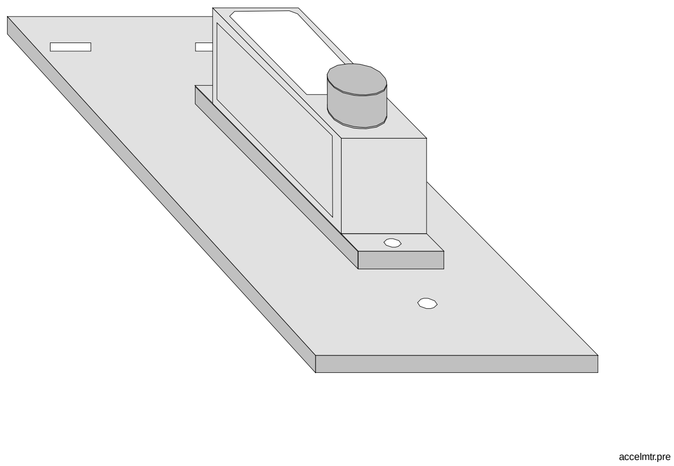


Figure 11 Accelerometer Assembly

1.2.4 Driver's Control Box 3CU 10043 ABAA

The Driver's Control Box (DCB) is shown below. It is integrated into the operator panel in each cab. It enables the Train Operator to select the mode of operation and door control.

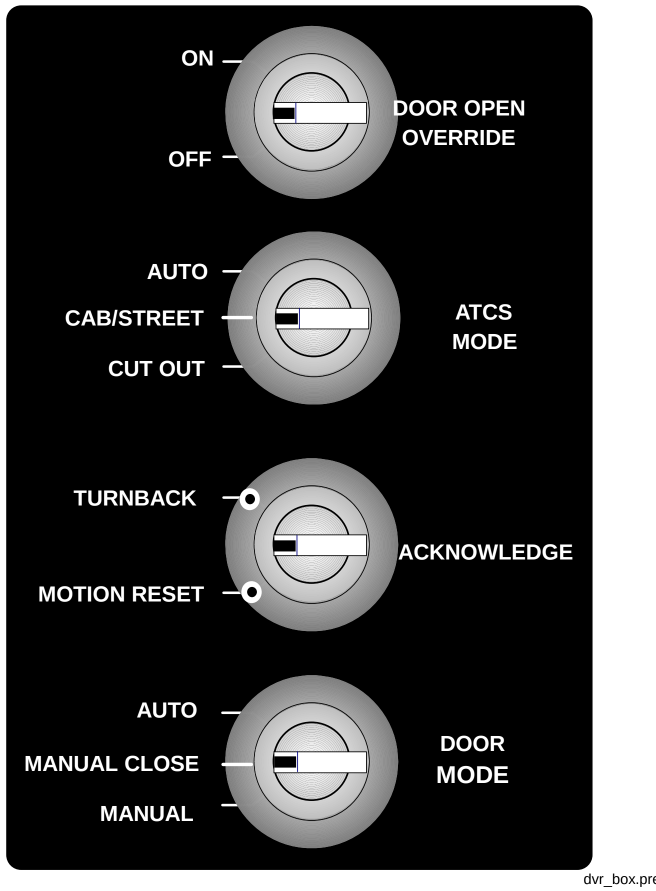


Figure 12 Driver’s Control Box

1.2.5 Train ID Unit **3CU 10022 ABAA**

The Train ID Unit is shown below. It is integrated into the operator's panel in each cab. It has three ten-position thumbwheel switches for operator entry of the RUCUS train ID.

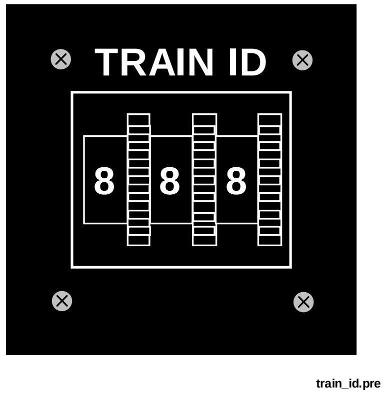


Figure 13 Train ID Unit

1.2.6 Driver's Display Unit **3CU 10044 AAAA**

The Driver's Display Unit (DDU) is shown below. A DDU is integrated into the operator's Panel in each cab.

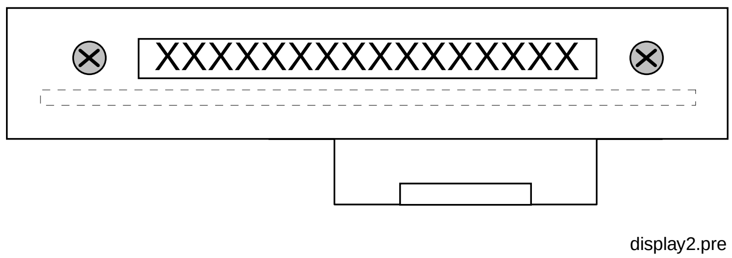


Figure 14 Driver Display Unit

1.2.7 Disconnect Unit **3CU 10041 ABAA**

The Disconnect Unit (DU) is shown below. One DU is installed in each Cab (in the 'A' and 'B' Ends).

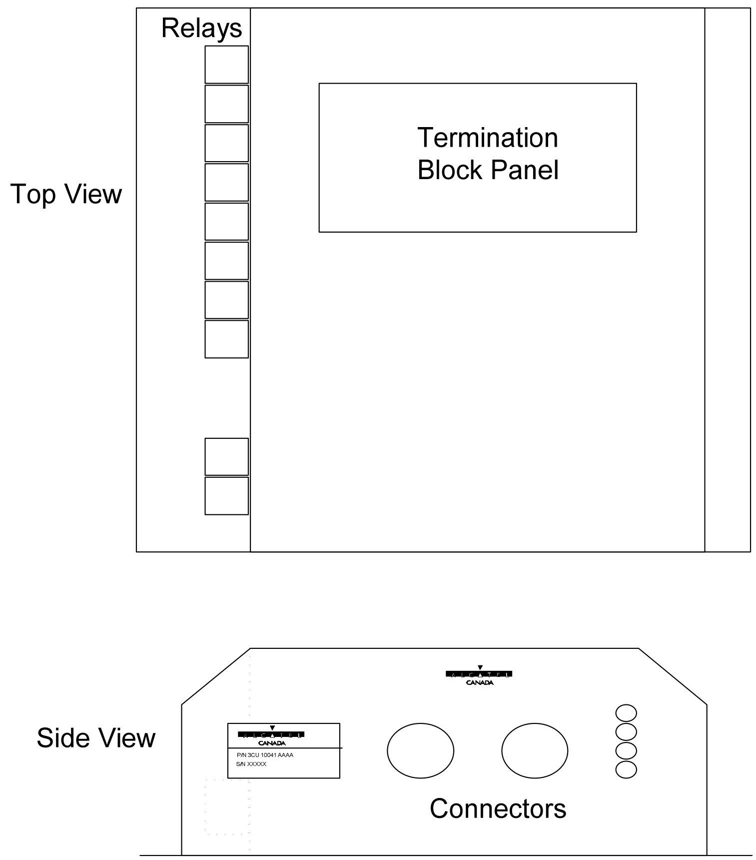


Figure 15 Disconnect Unit

1.2.8 Destination Sign Interface Box — 300-3-00246

The Destination Sign Interface Box translates the 8-bit parallel signal into a 'LonWorks' compatible code to display a route and destination combination. The codes have been programmed into the interface box and sent to the signs over the 'LonWorks' twisted pair network. The interface is mounted in the VOBC Rack. See the LRV2 VOBC

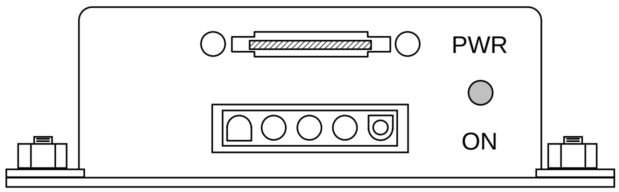


Figure 16 Destination Sign Interface Box

1.2.9 Digital Voice Announcement System 300-3-00278

The Digital Voice Announcement (DVA) is located in the 'A' cab of the LRV2. The DVA interfaces the VOBC CU to the vehicle Passenger Announcement (PA) system.

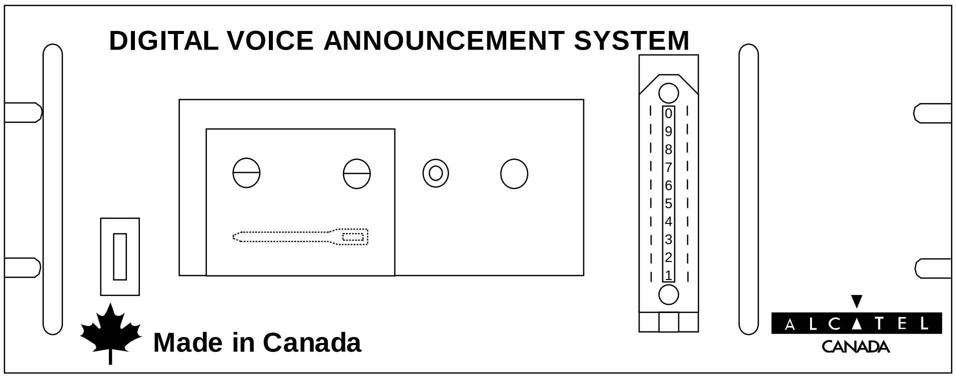


Figure 17 Digital Voice Announcement System

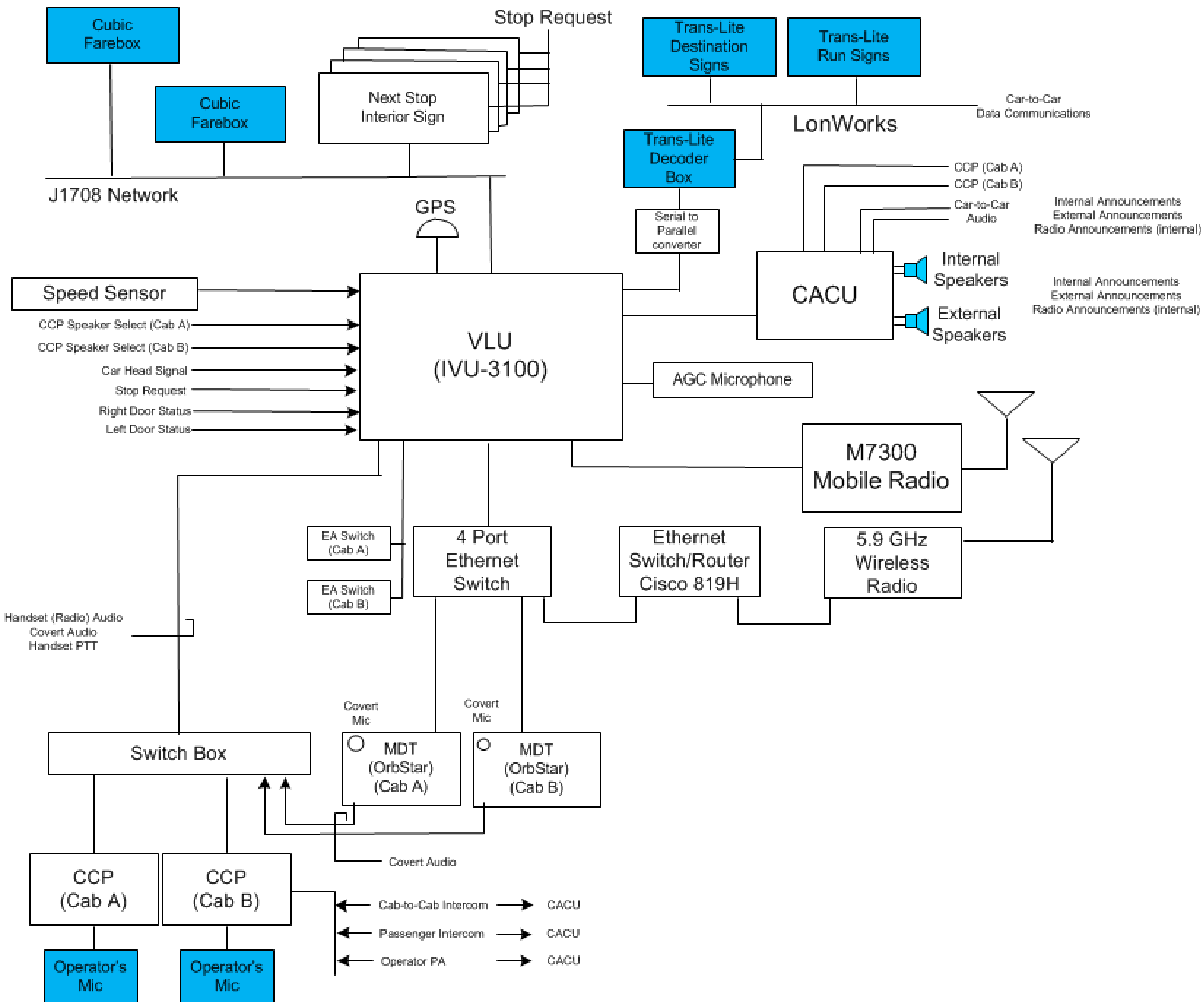
1.2.10 Cable Set

The following cables are part of the On-Board Equipment:

• Cable Assembly Output 1 2/CC 2	3CU 30001 ACAA
• Cable Assembly Input 1/2/3 CC4/5/6	3CU 30004 AAAA
• Cable Assembly Output 3/CC 3	3CU 30000 AGAA
• Cable Assembly FAR 3 4/CC 8	3CU 30001 AEAA
• Cable Assembly IMC 1 2/OP 4/CC 7	3CU 30002 ACAA
• Cable Assembly FAR 1 2/CC 1	3CU 30001 ADAA
• Cable Assembly TWR 1 2/IRU/ACCEL	3CU 30005 ABAA
• Cable Assembly Input 1/CC 9	3CU 30010 ADAA
• Cable Assembly Input 2/CC 10	3CU 30010 AEAA
• Cable Assembly Input 3/CC 11	3CU 30010 AFAA
• Cable Assembly CU IRU I/F	3CU 30014 AAAA
• Cable Assembly EU Power	403-2-00284-AAC
• Cable Assembly EU IRU RX F1	3CU 30081 AGAA
• Cable Assembly EU IRU RX F2	3CU 30081 AHAA
• Cable Assembly TX/RX RS232 EU/CU	3CU 30050 AAAA
• Cable Assembly Power Signal I/F	3CU 30100 ABAA
• Cable Assembly EU/IRU Propulsion	3CU 30052 AAAA
• Cable Assembly RS232 25S/Free End	3CU 30050 BVAA
• Cable Assembly RS232 9P/Free End	3CU 30050 BWAA
• Cable Assembly Power Signal I/F DVAS	3CU 30100 AHAA

5. Radio System

The figure provides a block diagram of the Radio and CAD/AVL System configuration for current LRVs.



Radio-CAD/AVL System Interfaces (Source Harris Contract 1240 Submittal 1-00048A_Interface Control Documentation_CDRL_Rev02)

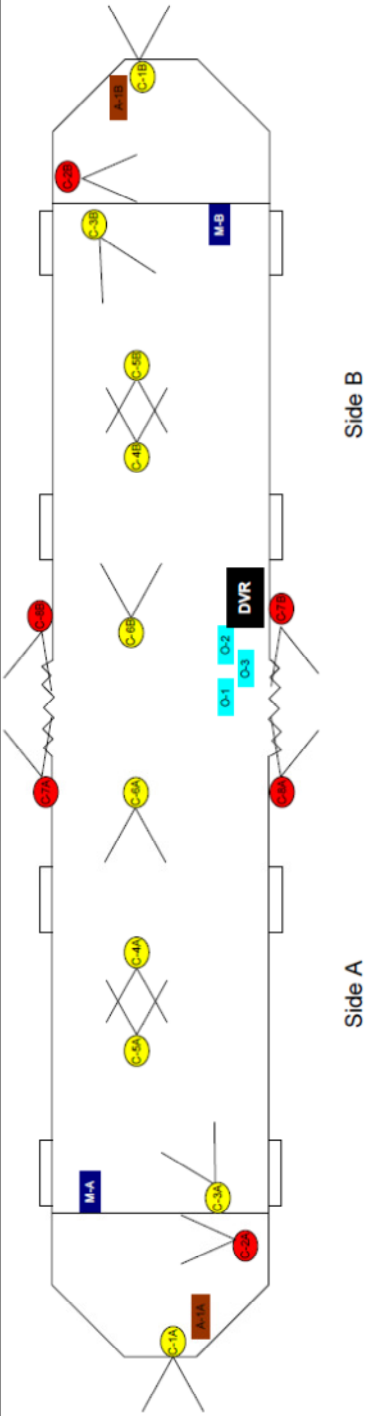
Contract title and number: **Radio System Replacement Contract No. 1240**	
Contractor's name, address, and telephone number: **Harris Corporation, 33 New Montgomery Street, Ste. 1420, San Francisco, CA, 94105, (415) 869-5500**	
Submittal number: **1-00048A_Interface Control Documentation_CDRL_Rev02**	
Category: **CDRL**	*Date:* **2-28-2013**
Subject Identification: **CDRL 12-1-05 Interface Control Documentation**	
Specification section and subsection numbers: **Appendix 12, 00900 Documents**	
SFMTA response due: **3-21-2013**	
Document Originator: **Abhinav Jain, Chris Kardish**	**Date:** **2/15/2013**
Engineering Peer Review: **Graham Buckberger**	**Date:** **2-26-2013**
Design Manager Review/Approval: **Daniel Buckley**	**Date:** **2-26-2013**
Project Management Peer Review: **Sean Munjal**	**Date:** **2-21-2013**
Contracts and Compliance Review: **Cynthia Bucci**	**Date:** **2-27-2013**
Back-check and Verification: **Personnel as noted above**	**Date:** **2-28-2013**
Contractor's approval stamp: APPROVED HARRIS Brent Geary, Project Manager	*Approval signature:*

Upon SFMTA approval of this CDRL, please fill out the below fields.

Action:	*Print Name:*	*SFMTA reviewer's signature:*	*Date:*

Action Column Key - (A - Approved) (B - Conditionally Approved as Noted) (C - Disapproved - Resubmit) (D - Rejected) (N - No Action Required)

6. CCTV Device Layout



Device	Description	Type	lens (mm)	DVR Channel	Input	Comments
C1A,B	Forward Facing	IP, Interior, Surface	4.0			
C2A,B	Operator	Analog, Interior, Surface	2.8			
C3A,B	Front Door	IP, Interior, Surface	2.8			
C4A,B	Front Section	IP, Interior, Surface	2.8			
C5A,B	Mid Section	IP, Interior, Surface	2.8			
C6A,B	Aisle Front Facing	IP, Interior, Surface	2.8			
C7A,B	Curbside Camera	Analog, Exterior, Surface	3.6			
C8A,B	Streetside Camera	Analog, Exterior, Surface	3.6			
MA,B	Microphone	Interior, Flush				
A1A,B	Status Tag Module	Interior, Surface				
O1	4.9GHz MIMO Antenna	Exterior, Surface (Roof)				
O2	4.9GHz MIMO Antenna	Exterior, Surface (Roof)				
O3	GPS Antnna	Exterior, Surface (Roof)				

1208 2,8 ip

302

LEGEND

- Analog Camera
- IP Camera
- Microphone
- Alarm Device
- Other Device

Customer:	San Francisco MTA
Project:	SF MTA-CPT 672
Drawing Name:	SF MTA_Device_Layout_lrv-60ft
Date:	7/23/13
Revision:	R – 7.0

APPENDIX B – MATERIALS AND WORKMANSHIP

This section is intended as an example of standard materials and workmanship requirements. It is SFMTA's intention that, at the Proposal stage, each bidder proposes its own criteria, where different, for approval. Upon completion of negotiations with the winning bidder, the agreed content will form Section 19 of the Specification document.

B.1 GENERAL

B.1.1 Standards

1. The latest version of all Standards, Specifications, and documents at the time of Contract Award shall apply.
2. When the Contractor proposes to use a standard other than those specifically applied herein, the Contractor shall submit documentation for SFMTA review and approval demonstrating the proposed standards are the equivalent of the foregoing standards and specifications.
3. Any testing required by this specification to confirm physical properties shall have been performed on materials representative of that used in the construction of this car
4. All finishes shall be vandal resistant and easily cleanable.

B.1.2 Prohibited Materials

1. The following materials are prohibited for use in the construction of these cars, except where specifically permitted:
    a. PVC
    b. Asbestos
    c. Lead in brake shoes
    d. Urethane Foam
    e. Cadmium (except for battery)
    f. Aluminum Threaded Fasteners
    g. PCB's
    h. Materials listed in 29 CFR 1910.19

B.1.3 Dissimilar Materials

1. In this context, dissimilar material refers to materials that corrode or otherwise become damaged when in contact with each other.
2. 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. As an option, permanent sealing at the contour of the connection may be used in lieu of electrochemical isolation.

3. Dissimilar materials are not permitted at electrical connections or connections requiring disassembly for maintenance or for removal and replacement of equipment.

B.1.4 Safety Reporting Requirements

1. The Contractor shall supply SFMTA with copies of Material Safety Data Sheets for all materials, including lubricants and preparation substances used in the fabrication of the vehicles. Information shall be in a form compliant with ANSI Z400.1-1993.

B.1.5 Requirements for Non-Conforming Material

1. Any Materials found to be non-conforming shall be brought into conformance or destroyed at the Contractor's expense.

B.1.6 Verification of Conformance with Requirements

1. Except where a specific test or inspection is called out in this section, the primary means of verifying conformance with the materials and workmanship requirements given in this section shall be the quality control and quality assurance programs required as part of Section 20 of this specification.

B.2 JOINING AND FASTENING

B.2.1 Applicability

1. The provisions of this section do not apply to welded or bonded joints, for such joints refer to Section B.7 (welded) or Section B.2.3 (bonded).

B.2.2 Joining

B.2.2.1 General

1. Certain combinations of materials require particular care in joining to avoid the possibility of corrosion (refer to Section B.1.3). The contractor shall design the vehicles to minimize the number of such combinations, and to minimize the accumulation of water, cleaning chemicals, and chemicals present in the environment, at or near joints. Isolating, sealing and/or moisture-proofing materials, appropriate to the materials being joined, shall be used at all times where these combinations exist.

B.2.2.2 Joint Fitting

1. Joints shall be properly fitted, whether exposed or concealed.
2. The edges of panels shall have a smooth, finished appearance.
3. Where excessive gaps (greater than those permitted by approved drawings or standards) are found to exist at the faying surfaces of structural bolted or riveted connections, metal shims of the same material as that of the deficient part may be used, but only with the written permission of SFMTA.
4. Shims, if used, in connections requiring disassembly for maintenance or for removal and replacement of equipment, shall be permanently fastened to one of the base parts

being joined. The use of epoxy or other plastic filler at such locations is expressly prohibited.

B.2.2.3 Metal-to-Metal Connections

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

B.2.2.4 Wood-to-Metal Connections

1. The provisions of this Section do not apply to ply metal panels and their installation (refer to Section B.15.2).
2. Where wood and ferrous metal surfaces are placed together:
    a. the wood shall be coated with aluminum paint conforming to the latest version of Federal Specification TT-P-38, related to aluminum paint.
    b. the metal shall be coated with a primer which conforms to the latest version from the Society for Protective Coatings Specification SSPC-25 at the time of NTP.
3. All bolts or rods passing through wood shall be coated with aluminum paint conforming to the latest version of Federal Specification TT-P-38 related to aluminum paint at the time of NTP.

B.2.2.5 Wood-to-Wood Connections

1. Where wood and wood are placed together, both abutting surfaces shall be coated with aluminum paint conforming to the latest version of Federal Specification TT-P-38 related to aluminum paint.

B.2.3 Fasteners

B.2.3.1 General

1. The Contractor and suppliers are responsible for selecting fastener types, sizes, styles, lengths, materials, grades, and finishes that shall meet the requirements of this Specification.
2. The Contractor shall minimize the number of different sizes and styles of fasteners used.
3. All fasteners used can be classified under one of four categories: critical; electrical and electronic; decorative; or general purpose. The criteria for classification are expressed below. All fasteners must meet the general requirements for design and material in addition to any requirements contained in the section specific to the particular

category. All fasteners, in any category, which attach to car structure shall be in accordance with Technical Specification.

4. Critical fasteners include, but are not limited to, all fasteners applied to carbody structure, trucks, bolsters, truck-mounted brake equipment, couplers, and power collection devices. Additionally, any fastener is considered critical if failures cannot be tolerated, that is, if even a single fastener fails there is a possibility of brake failure, derailment, accident or injury or equipment falling. In the event of a dispute, SFMTA shall be the final arbitrator on which fasteners are classified as critical.
5. Fasteners used to secure wire terminations to an electrical or electronic device are considered Electrical and Electronic, and are specified in appropriate Materials and Workmanship subsections for electrical devices and wiring.
6. Fasteners used to attach interior lining or trim and exposed to passenger view are specified under Decorative Fasteners.
7. Fasteners not falling into one of the other three categories are classified as General Purpose.

B.2.3.2 Inch-Standard Fasteners

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

B.2.3.3 Metric Fasteners

1. All metric threaded fasteners shall conform to the latest version of ANSI or (ISO-metric) Standards.
2. For either inch-standard or metric fasteners, all repair and maintenance manuals shall be conspicuously marked on each page which fasteners were used within the unit.
3. Replacement, repair, or maintenance parts supplied under this Specification shall contain all necessary replacement fasteners of the correct size and grade.
4. Metric and inch-standard hardware shall not be mixed within an assembly.

B.2.3.4 Fastener Materials and Coatings

1. When making connections to heat producing apparatus, thermal expansion of the components shall be taken into consideration for selection of fastener materials.
2. All fastener materials and coatings shall be approved by the SFMTA.

B.2.3.5 Joint Design

1. All screws or bolts used to secure access panels to the interior, undercar, or roof equipment shall be made captive to the panel in which they are used.
2. All fasteners used to secure access covers, doors, or panels to equipment boxes or interior panels shall be made captive to the panel in which they are used.
3. Unless otherwise approved by SFMTA, threaded fasteners shall not be threaded directly into non-metallic materials. Metal thread inserts shall be used when a threaded fastener is secured to a non-metallic material.

4. When bolts are used to secure apparatus where the bolt head is not accessible, a reusable mechanical locking device shall be used to prevent the bolt head from turning when the nut is being turned.
5. At least 1-½ screw threads shall be visible beyond all nuts. When used without elastic stop nuts, bolts shall not project more than 1-½ threads plus 0.25-inch for bolts 0.25-inch diameter or less and shall not project more than 8 threads for larger diameter bolts, unless otherwise approved.
6. With elastic stop nuts, bolt threads shall not project more than 0.25-inch, regardless of bolt size.
7. Undercar equipment shall not be supported by bolts in tension.
8. All fasteners shall be torqued to a value appropriate to the application, so that they do not loosen in service. Critical fasteners and general purpose fasteners used to secure equipment to the carbody, including truck and brake equipment bolts and all fasteners exposed to fatigue loads, shall be "torque sealed" or "torque striped" after torquing by paint or other approved means.
9. Locknuts shall be torqued in accordance with their manufacturer's recommendations or the Contractor may conduct tests to determine installation torque.

B.2.3.6 Critical Fasteners

1. All critical fasteners shall have documentation identifying manufacturer and purchase specifications available for examination by SFMTA at the Contractor's QA department.
2. This documentation shall include the fastener material or grade, and finish including plating material and specifications, when applicable. Whether the buyer is a sub-contractor, supplier, or the Contractor, the Contractor shall obtain and hold this documentation for a period of not less than termination of the last car's warranty period. After this period, all documentation shall be provided to SFMTA
3. All critical fasteners shall be manufactured, tested, and distributed in accordance with ASME FAP-1-1990 or equivalent approved by the SFMTA.
4. Testing of critical fasteners shall be performed using sample quantities as proposed by the Contractor and approved by SFMTA. Tests conducted shall confirm that fastener material meets specified chemistry and strength requirements.
5. The buyer shall obtain certified test results for critical fasteners from the testing laboratory and hold the documents for a period at least until the termination of the warranty period of the last car. After this period, all documentation shall be provided to SFMTA.
6. All critical fasteners that are plated or chemically cleaned shall have certifications showing freedom from hydrogen embrittlement.

B.2.3.7 General Purpose Fasteners

1. As much as possible, Grade 5 bolts and Class A nuts shall be used for installation of equipment and/or structures.

2. Fasteners used within equipment shall meet all requirements of this Section other than the requirements specifically listed for critical fasteners or decorative fasteners, and shall be sized as appropriate for the application.

B.2.3.8 Decorative and Appearance Fasteners

1. All interior fasteners exposed to passengers shall be either bright or finished to match the surfaces being joined, and installed such that the fastener head is flush with the mating surface.
2. Fasteners on access panels, plates, covers, or other components accessible by passengers shall be of a single style tamperproof type approved by SFMTA.

B.2.3.9 Rivet and Bolt Holes

1. Rivet and bolt holes shall be accurately located and aligned, and, when necessary during assembly, holes shall be reamed round to specified size in position. Hand-driven steel rivets shall be driven hot and shall completely fill the holes. Mechanically driven rivets may be driven cold. Heads shall be concentric with the shank of the rivet. Exposed heads shall be free from rings, fins, pits, and burrs. All removed and replaced rivets shall have the holes reamed to the size required such that the next larger rivet may be driven securely.

B.2.3.10 Quarter-Turn Fasteners

1. Quarter-turn fasteners can be used in areas where access is needed to service equipment or perform emergency functions. Quarter-turn fasteners shall have a minimum shank diameter of ¼-inch, and shall be of adequate strength. All quarter-turn fasteners shall be made captive to the panel in which they are used.

B.2.4 Bonding

1. All adhesive applications shall be suitable for the materials being joined and the environmental exposure to be expected. The Contractor shall submit to SFMTA manufacturer's data for all proposed adhesive applications prior to first use of the adhesive system.

B.3 STAINLESS STEEL

B.3.1 General

1. General requirements for delivery of stainless steel shall be as defined in ASTM A480.
2. In order to avoid difference in appearance, abutting or closely spaced unpainted parts exposed to passengers shall be made of the same grade of stainless steel and shall have matching surface finish, except where the design specifically calls for contrasting appearance.
3. For welded applications, only low carbon stainless steels grades shall be used.
4. Connections of stainless steels to carbon/HSLA steels shall be protected against galvanic corrosion.

B.3.2 Application

B.3.2.1 Austenitic Stainless Steel

1. Austenitic stainless steels used in structural applications shall conform to APTA SS-C&S-004-98 Standard for Austenitic Stainless Steel for Railroad Passenger Equipment.
2. Austenitic stainless steels may be unpainted.

B.3.2.2 Ferritic and Martensitic Stainless Steel

1. Ferritic and martensitic stainless steels shall conform to ASTM A176 and/or A240. Other grades may be used if approved by SFMTA. Structural applications of ferritic and martensitic steels shall be submitted to SFMTA for approval. Depending on application, SFMTA may require proof of ductility and/or crashworthiness of selected base metals and of their welded joints. Details of required tests and acceptance criteria shall be agreed between the supplier and SFMTA.
2. Low-chromium ferritic and martensitic stainless steels, which depending of application may be subject to corrosion, shall be painted.

B.4 HIGH STRENGTH LOW ALLOY STEEL

1. High Strength Low Alloy (HSLA) steel may be used in the carbody structure to the extent defined by the supplier. General requirements for delivery of HSLA steel shall be in conformity with ASTM A6 for plate steel and A568 for sheet steel.
2. Characteristics of selected plate steel shall ensure meeting welded joints impact strength per 19.7.10. Only material with certified impact strength shall be used. Base metal toughness shall be certified on a heat basis by the steel manufacturer or steel supplier; if these data are not available, the Contractor shall perform tests on each heat of as-received base metal.
3. Depending on application of sheet steel, the customer may require proof of ductility and/or crashworthiness of the selected base metal and of its welded joints. Details of required tests and acceptance criteria shall be agreed between the supplier and SFMTA.
4. All HSLA steels shall be primed and painted.

B.5 STRUCTURAL CASTINGS

B.5.1 General

1. The Contractor shall be responsible for selecting casting grade, composition, strength, and finishing. Mechanical properties of steel castings, used in the carbody structure and truck assemblies shall meet or exceed the strength required by the specified application, as determined by the SFMTA.
2. Steel castings used for coupler, drawbars, and anchors shall meet AAR Specification M-201, latest revision, Grade “C” or “E”, quenched and tempered.

3. Where cast steel of superior properties is required for a specific application, the Contractor may propose such castings for review and approval of SFMTA.
4. The chemical composition and processing of stainless steel castings must be selected such that the castings shall be able to meet or exceed the strength required by the specified application, as determined by the SFMTA. Stainless steel castings shall be made in accordance with appropriate ASTM standard(s), depending on the type of stainless steel used. Other standards may be used upon SFMTA approval.

B.5.2 Design Qualification of Structural Castings

1. One steel casting, selected by SFMTA from the first lot of production steel castings, shall be subjected to a qualification test of the casting design by the Contractor. A statistical sample of stainless steel castings, as agreed upon by the SFMTA and the Contractor, from the first lot of production stainless steel castings, shall be subjected to a qualification test of the casting design by the Contractor.
2. Qualification tests shall include radiographic examination for material soundness using reference radiographs to ASTM E 446 and any mechanical testing.
3. Acceptance levels for the design qualification radiographic examinations shall be selected by the Contractor as appropriate for the service intended, subject to the approval by SFMTA before any castings are produced. Radiographs shall meet the requirements of ANSI/ASTM E 94 and E 142 for steel castings, and ASTM E 1742 for stainless steel castings, and the quality level in the area of inspection shall be at least two percent (2-2T).
4. Once a design is qualified and accepted by SFMTA, no changes shall be made in the casting pattern, technique, heat treatment, or material composition without requalification in accordance with the requirements of this Section.

B.5.3 Structural Casting Inspection

B.5.3.1 Magnetic Particle Inspection

1. Magnetic particle inspections of all surfaces of each casting shall be conducted, in accordance with ASTM E 709, by personnel certified to MIL-STD-410. With respect to structural castings, including coupler castings, the maximum permissible magnetic particle indications shall be not more than ¼-inch in the direction transverse to the usual direction of loading, and no more than ¾-inch in the direction parallel to the usual direction of loading.
2. For martensitic and ferritic stainless steel castings, acceptance criteria shall be in accordance with ASTM A 903.

B.5.3.2 Radiographic Inspection

1. Radiographic inspection of steel castings shall be conducted according to the requirements of ASTM Standards E 94 and E 142, using reference radiographs to ASTM E 446. Radiographic inspection of stainless steel shall be conducted according to the requirements of ASTM Standards E 94, E 1742 and E 1030. A sampling frequency shall be proposed by the Contractor and submitted for approval by SFMTA.

2. Structural castings shall not exceed severity level 3 of ASTM E 446 in all critical areas of such castings and shall not exceed level 5 in all other areas of the castings. During demonstration that the stated severity level requirements of ASTM E 446 have been met, successively produced castings shall be re-inspected by radiography in the defective areas shown in the prior radiographic inspection. After such severity levels have been proved, the sampling frequency for structural castings shall be one casting out of each 10 produced. If no castings are rejected by radiographic inspection, this frequency may be extended to one casting in 25.

B.5.3.3 Liquid Penetrant Inspection

1. When required for non-magnetic stainless steel castings, liquid penetrant inspections of casting surfaces shall be conducted according to ASTM E 165, by personnel certified to MIL-STD-410. Acceptance criteria shall be established in accordance with ASTM A903.

B.5.4 Repair Welding

1. Repair welding of steel castings is permitted, provided the casting supplier performs all repair welds according to the structural welding requirements of this specification. Repairs or modifications by welding of castings after completion of heat treatment shall require precautions such as preheat or stress-relief heat treatment. Either operation may be applied to the whole part or locally. The temperature of the stress relief treatment shall not be above tempering temperature of the original heat treatment. Manual torch stress relief shall not be permitted except for cosmetic welds and only then after the procedures have been submitted for review and approval.

B.5.5 Cast-Weld Design

1. For cast-weld designs, the entire length of all assembly welds on any welded assembly of several separate castings selected for design qualification shall be radiographically inspected to ANSI/ASTM E 94 and E 142, using reference radiographs from the International Institute of Welding's "Collection of Reference Radiographs of Welds," quality level Green. Portions of assembly welds stressed in tension by service loads shall meet quality level Blue.
2. No repair welding of stainless steel castings is permitted without express written approval of the SFMTA.

B.6 ALUMINUM

B.6.1 General

1. Aluminum alloy mill products shall be identified by Unified Numbering System designations and shall conform to The Aluminum Association specifications contained in the Association's publication "Aluminum Standards and Data".
2. Aluminum alloy castings shall conform to ASTM B26, B85, or B108 for, respectively, sand, die, or permanent mold castings.
3. Aluminum alloy forgings shall conform to ASTM B247.

4. Copies of all test reports for sheet, extrusion, castings, and forgings used in the car structure shall be submitted to SFMTA.

B.6.2 Fabrication and Fastening

1. The forming of aluminum parts; joining of parts by bolting, riveting, and welding; and the protection of contact surfaces shall, as a minimum, conform to the requirements of this specification.
2. Fabrication techniques shall be such that the strength and corrosion resistance of the aluminum shall not be impaired nor the surface finish permanently affected during construction.

B.6.3 Interior Trim

1. Unpainted aluminum used for interior trim shall have a clear (natural) anodic finish. The finish process shall be the Aluminum Company of America's "Alumilite 204" with a minimum coating thickness of 0.0004 in and a minimum coating weight of 21 mg/in^2, or approved equal.

B.7 WELDING AND BRAZING

B.7.1 General

1. The Contractor shall be responsible for the quality of its welding and brazing as well as that of its suppliers and subcontractors.

B.7.2 Structural Welding

1. All structural welding practices shall be according to the latest requirements (at the time of NTP) of the American Welding Society or International Standards related to the materials submitted and approved by the SFMTA. All Welding will be performed by AWS certified welders, or other recognized international standard, subject to approval of the SFMTA.
2. Structural fusion welding practices, including establishment and qualification of welding procedure specifications, shall be according to the requirements of the following American Welding Society standards:
   a. AWS D1.1, "Structural Welding Code–Steel".
   b. AWS D1.2, "Structural Welding Code – Aluminum".
   c. AWS D1.3, "Structural Welding Code - Sheet Steel".
   d. AWS D15.1 "Railroad Welding Specification for Cars and Locomotives".
3. Cast steel welding shall be according to AWS D15.1 or ASTM A 488/488M, "Steel Castings, Welding, Qualification of Procedures and Personnel".
4. AWS D1.1 and AWS D15.1 shall apply to steel of $^{1}/_{8}$-inch and greater thickness. AWS D1.3 shall apply to steel less than $^{1}/_{8}$-inch thickness.
5. Alternative standards may be submitted to SFMTA for approval.

6. Welding procedure specifications and procedure qualification records shall be made available to SFMTA for review.

B.7.3 Welder Qualification

1. Welders shall make only those welds for which they have been qualified according to the requirements of the applicable AWS standards listed in Section B.7.2. Alternative standards may be submitted to SFMTA for approval. Records of welder qualification tests shall be made available for review.

B.7.4 Inspection of Welds

1. The Contractor shall visually inspect all structural welds in accordance with requirements of applicable standards.
2. Nondestructive surface inspection (liquid penetrant or magnetic particle methods, as appropriate) shall also be used to inspect all first-production welds. The Contractor shall specify a nondestructive surface inspection sampling plan for all subsequent welds. A record of all NDT inspections shall be included in the Car History Book.
3. On the first structure, and where practicable, all complete joint penetration welds shall be nondestructively, volumetrically inspected (ultrasonic or radiographic methods) according to requirements of applicable standards. For subsequent welds, the Contractor shall specify a volumetric inspection sampling plan which shall be submitted to SFMTA for approval. The proposed test welds shall be selected from welds that are most critically loaded as determined by calculation or load test. With approval of SFMTA, destructive sectioning and metallographic examination may be substituted for some or all of the required volumetric inspection requirements for production welds.

B.7.5 Post-Weld Cleaning Requirements

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

B.7.6 Dissimilar Metal Welding

1. In dissimilar metal welding, recommended practices of AWS D1.6, Annex I, shall be followed.
2. Galvanized steel shall not be welded to stainless steel.

B.7.7 Resistance Welding

1. Resistance welding practices, including establishment and qualification of welding procedure specifications, shall be according to the requirements of the following American Welding Society standards:
    a. AWS D17.2 “Specification for Resistance Welding for Aerospace Applications”.
    b. AWS C1.1 “Recommended Practices for Resistance Welding”.
    c. Alternative standards may be submitted to SFMTA for approval.

2. Resistance welds steels shall be according to AWS D17.2, Class B for structural applications and Class C for non-structural applications. All resistance welding procedures shall be qualified per AWS D17.2. Welding procedure specifications and procedure qualification records shall be made available to SFMTA for review. Contractor-proposed deviations from AWS D17.2, including, but not limited to, weld nugget diameter, tension shear strength, and minimum spacing, shall be submitted to SFMTA and approved before application in production.
3. 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. For exposed welds, the Contractor shall vary welding parameters and conditions within their acceptable ranges to minimize indentations. Surface burn and discoloration shall be removed by chemical cleaning, or an approved equal method, and sanding or polishing to match the surrounding surface.
4. Production witness welds shall be made and tested once each day and, in addition, whenever otherwise necessary such as by change in any of the following:
    a. Operator.
    b. Material, material thickness, or combination of thicknesses.
    c. Electrodes.
    d. Settings.

B.7.8 Resistance Spot Weld Spacing

1. Spacing of resistance and spot welds shall be according to approved structural drawings. Spacing of welds contributing to carbody stiffness shall not exceed 2 inches plus twice the weld nugget diameter for any structural application, including carbody side sheets, roof sheets, and corrugation. For any application to corrugations, if the pitch of the corrugation nodes does not allow the above weld spacing, there shall be two (2) spot welds between each node.

B.7.9 Intermittent Fusion Welds

1. Total length of weld segments in intermittent structural welds shall represent at least 40% of the total joint length.

B.7.10 Toughness of Welded Assemblies

1. In the absence of prior operating history, and if the Contractor's approved design does not require greater toughness, the minimum impact value for Charpy V-notch welded joint specimens tested to AWS D1.1 Code shall be 15 foot-pounds of absorbed energy at -20ºF.
2. SFMTA shall have the right to require impact tests to verify the specified toughness. If tests are required, verification of HAZ toughness shall be done on a test sample welded according to Procedure Qualification Record (PQR) parameters.

B.7.11 Torch Brazing

1. All brazing shall follow the recommendations of the AWS Welding Handbook, Volume 2, latest issue. Procedures and personnel who perform brazing work shall be qualified in accordance with AWS B2.2, "Standard for Brazing Procedure and Performance Qualification". Brazing procedures and records of brazing procedure and performance qualification shall be available to the SFMTA.

B.7.12 Torch Soldering

1. All structural (not electrical) soldering shall follow the recommendations of the AWS Welding Handbook, Volume 2, latest issue. Procedures and personnel who perform torch soldering shall be qualified through the preparation and testing of samples of production torch soldering. Soldering procedures and records of soldering procedure and performance qualification shall be available to the SFMTA.

B.8 ELASTOMERS

B.8.1 General

1. Elastomers shall be compounded and cured to perform satisfactorily in the environment specified in Section 2. The elastomers shall have high resistance to ultraviolet radiation, weather, and all SFMTA car washing and other cleaning fluids. All elastomeric parts shall be resistant to ozone, oxidation, heat, oil, grease, and acid, and have the longest possible life consistent with the other characteristics specified.
2. The following elastomeric parts shall be of neoprene and shall have a minimum service life of ten (10) years, unless otherwise specified or approved:
   a. Glazing Rubber.
   b. Door Seals.
   c. Door Nosing.
   d. Isolation Tapes/Pads.
   e. Other parts exposed to the outdoor ambient environment, except where otherwise specified.
3. All resilient mounts and elastomeric truck components shall be of natural rubber. Synthetic rubber compounds may be substituted for natural rubber only when approved by SFMTA for a specific application.
4. Elastomeric parts within pneumatic or hydraulic equipment shall be as necessary to meet the performance requirements of this Specification for the pneumatic or hydraulic device.

B.8.2 Life Expectancy

1. All resilient parts shall have a design life no less than the required overhaul period.
2. For all parts made by vulcanizing an elastomer to metal, any premature failure (before the replacement period specified in the maintenance manual) 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.

B.8.3 Bonded Steel Parts

1. Steel 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.

B.8.4 Bonding

1. The joining of elastomeric pieces shall be conducted by the hot vulcanization process. Bonding of elastomers by other processes shall not be allowed unless the Contractor submits the application, bonding procedure and bonding agent technical data for approval.

B.8.5 Seals

1. Glazing strips shall be of neoprene conforming to ASTM C 542, or approved equal material.
2. 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.

B.9 GLAZING MATERIALS

B.9.1 General

1. Safety glass shall meet the requirements under Item 1, Table 1 of ANSI Z26.1, "American National Standard for Safety Glazing Materials for Glazing Motor Vehicles and Motor Vehicle Equipment Operating on Land Highways – Safety Code," or 49 CFR 223 and 238 FRA Type I or II test as appropriate for the application.
2. Windows shall be covered with graffiti-resistant film on the interior after installation.

B.9.2 Flatness

1. When an individual light of glass is laid on a truly flat surface such as a surface plate, the glass shall not indicate a bow of more than 0.030-inch per linear foot in any direction.

B.9.3 Overlap Tolerance

1. The overlap of one laminate of the light with respect to the other at an edge shall not exceed $^{1}/_{32}$-inch. Corners and burrs shall be ground smooth and all edges shall be treated in accordance with ANSI Z26.1, Section 6.

B.9.4 Tint/Color

1. The color of the glass shall be a tint similar to what is currently used and shall not allow more than76% transmission of light and 77% transmission of energy or as accepted by SFMTA. When new, there shall be no more than +/- 4 percent variation in

the color of individual lights of laminated sheet glass when examined over a white background.

B.9.5 Haze

1. All the laminates of the safety glass shall be so nearly free from haze that the glass shall have approximately the same clarity as a light of the same nominal thickness of plate glass when viewed against a north light.

B.9.6 Specks and Scratches

1. Occasional specks of foreign material and scratches will be permissible, provided such specks do not exceed 0.020-inch in greatest dimension and scratches do not exceed a total of 3 inches in length, and neither are within the central three-quarters area of the light.

B.9.7 Bond Separation

1. The bond between two sheets of glass and the membrane shall be of such quality that when the glass is broken by twisting or by direct impact, there will be no separation between the glass sheets. Lights that contain unbonded areas shall not be used.

B.9.8 Light Transmission

1. Average visible light transmission through clear safety glass shall be a minimum of 85%.

B.10 FLOOR COVERING

B.10.1 General

1. Floor covering shall be non-staining, non-discoloring and non-slip.
2. If used, rubber flooring material shall be fully homogeneous throughout and shall meet the requirements of ASTM F 1344 or equivalent standard approved by SFMTA.

B.11 PIPING AND TUBING

B.11.1 General

1. All piping shall be sized in accordance with the function intended.
2. All piping, valves, fittings, installation methods and testing shall be in accordance with the latest edition of ANSI B31.1 Pressure Piping or equivalent standard approved by SFMTA.
3. Following installation, all piping systems shall be cleaned to remove dirt, metal chips, oily contamination, and moisture. After cleaning, all piping systems shall be pressure tested in accordance with the latest edition of the Code for Pressure Piping, ANSI B31.1 or equivalent standard approved by SFMTA. All leaks shall be repaired and the system retested until leak free.

4. At all locations where pipe or tubing passes through holes in the floor, bulkheads, structure, or any fixed member, it shall be rigidly clamped to protect against possible damage or noise due to bearing, abrasion, or car dynamics-induced rattling. Clamps shall not be welded, brazed or otherwise permanently fastened to any pipe or tubing.
5. Wherever carbody piping interfaces with vibration-isolated rotating equipment such as the air compressor and air conditioning compressor-condenser unit, approved flexible vibration eliminators shall be used. All clamps shall be of a suitable material for the application.

B.11.2 Air Piping, Tubing, and Fittings

1. All air piping shall be installed in a manner to provide drainage away from devices, or branch pipes leading to devices, when the function of those devices could be impaired by the accumulation of water or ice.

B.11.3 Air Conditioning System Piping and Fittings

1. Air conditioning refrigerant lines and condensate drain lines shall be type “K”, seamless copper tubing with wrought copper sweat type fittings. Finned tubing in evaporators and condensers need not be type “K”. Tubing shall be bent with an appropriate tube bending tool.
2. All condensate drain lines and suction line piping shall be insulated with an approved insulation that meets the smoke and flammability requirements of this section. 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 a suitable contact cement. All joints and directional changes in the insulation shall be appropriately mitered and sealed with an approved material.
3. All piping shall be deburred after cutting and thoroughly cleaned after installation in accordance with this section. All piping and pipe sub assemblies shall be cleaned, dried (if required) and capped on all openings after fabrication. Caps shall remain in place until immediately prior to incorporation into the final assembly.

B.11.4 Brazing and Soldering of Piping and Fittings

1. All refrigerant and air system copper piping shall be joined using silver-based or silver-copper-phosphorus filler metals conforming to the AWS A5.8 Specification for Filler Metals for Brazing and Braze Welding, classifications BAg-5 or BCuP-5, or equivalent filler metals approved by SFMTA. During brazing, inner side of refrigeration tubing shall be protected with a continuous flow of an inert gas such as dry nitrogen.
2. Condensate drain tubing and air piping shall be joined using 95-5 solder or silver-based filler metal as above.
3. After fabrication, the system shall be cleared of all dirt and foreign matter, evacuated, dried and charged according to an approved procedure.
4. Brazed and soldered joints shall be wiped and have flux cleaned.

B.11.5 Pressure Vessels

1. All pressure vessels shall conform to the latest revision of Section VIII of the ASME Boiler and Pressure Vessel Code for Unfired Pressure Vessels or equivalent standard approved by SFMTA. Reports shall be provided demonstrating compliance.

B.12 AIR FILTERS

B.12.1 High Pressure Air Filters

1. Air filter assemblies with replaceable filter elements shall be provided in the air line that connects each subsystem to the air supply system. The filtering capability, flow rate capability, and overall size shall be appropriate for the application.

B.13 PAINTS AND COATINGS

B.13.1 General

1. The portion of the car body, or any of its components, receiving paint shall be painted as required by the Specification and in accordance with the specified color scheme and procedures recommended by the paint manufacturer for the application. The Contractor and its paint supplier shall supply a touch-up procedure and assure that a continuing supply of touch-up paints in colors used on the car, suitable for spot application by spray or brush, will continue to be available.

B.13.2 Materials and Preparation

1. Preparation of the substrate surface and application of painting materials shall be in accordance with the paint supplier's recommendations. All paint materials shall be used at the consistency recommended by the paint supplier. If thinners are necessary, they shall be approved by the paint manufacturer and shall be used only to the extent recommended.
2. The supplier shall submit color samples for approval.

B.13.3 Underfloor Paint

1. All undercar metallic parts, except stainless steel, which may be left unpainted in accordance with this specification, shall receive an epoxy finish or equivalent approved by the SFMTA.

B.13.4 Exterior Finish Painting

1. All exterior surfaces that are to be painted shall be prepared and the paint shall be applied according to the paint manufacturer's recommendations. The paint shall be uniformly applied over all surfaces to be covered and shall be free from runs, sags, or other application defects. Painting shall be done in a clean, dry atmosphere at an ambient temperature as recommended by the paint manufacturer.
2. Before painting any car surface that is exposed to view, all dents, gashes, nicks, roughness, or other surface imperfections or depressions shall be removed so far as

possible by straightening and shall be properly prepared to receive the filler material. These surfaces shall be properly cleaned and wash primed following straightening. Any remaining dents or other surface imperfections shall then be filled with an approved filler and sanded smooth.

3. The finished exterior shall present a high quality appearance free from sags, drips, scratches, variations in gloss, and other imperfections.

B.13.5 Apparatus and Equipment Enclosures

1. All underfloor and roof mounted apparatus and equipment enclosures (motors, control boxes, junction boxes, brake valves, and other equipment as specified) shall be primed and painted.
2. The interior and exterior surface of all propulsion control equipment enclosures shall be coated with an insulating paint system. The interior of the boxes, including insides of covers, shall be white and the exteriors shall match the surrounding paint scheme.

B.13.6 Miscellaneous Painting and Finishing

1. 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 1 coat of an approved sealer.

B.13.7 Painting Restrictions

1. Any equipment or parts of equipment which would be damaged or suffer impaired operation from painting shall not be painted and shall be corrosion resistant.
2. The following undercar items shall not be painted:
    a. Flexible conduit and fittings.
    b. Copper tubing, piping and fittings.
    c. Wire and cable.
    d. Power resistors.
    e. Heat transfer surfaces.
    f. Electrical insulators.
    g. Elastomeric parts.
    h. Grounding pads.
3. The following truck-related items shall not be painted:
    a. Elastomeric parts.
    b. Grease fittings.
    c. Linkages.
    d. Threaded parts used for adjustments.
    e. Electrical equipment.
    f. Current pick-up devices.

g. Wearing surfaces.
h. Grounding pads.
i. Wire and cable.

B.13.8 Interior Painting

1. Interior surfaces requiring paint shall be painted in accordance with the recommendations of the paint manufacturer.

B.13.9 Corrosion Protection

1. Concealed surfaces which may be subject to corrosion such as open-section beams of the structure frame shall be properly cleaned, receive a wash primer, then primed with an epoxy paint or equivalent approved by SFMTA.
2. Where arc welding is performed on joints between stainless steel and other materials, the joint shall be painted in accordance with this Section.

B.13.10 Acoustic Insulation

1. Acoustic insulating materials shall be applied to properly cleaned and primed underframe, sides, ends, roof and floor members, as required in accordance with the supplier's recommendations. The materials shall be resistant to dilute acids, alcohols, grease, gasoline, aliphatic oils and vermin and shall meet the smoke and flammability requirements.
2. The material shall be unaffected by sunlight and ozone and shall not become brittle with age.

B.13.11 Truck Painting

1. All truck components to be painted shall be given a full coat of primer prior to assembly.

B.13.12 Lettering and Numbering

1. Lettering and numbering shall be applied to the interior and exterior of the car by means of decals approved by the SFMTA. Decals shall be applied and edge sealed in accordance with manufacturers' recommendations.
2. All decals shall be formulated and applied such that removal does not damage the underlying paint or surface.

B.14 FLAMMABILITY AND SMOKE EMISSION REQUIREMENTS

B.14.1 General

1. All combustible material used in the construction of the car shall satisfy the flammability, smoke emission, and toxicity requirements, NFPA 130 or a standard approved by the SFMTA. A report of all materials used and a Smoke, Flame, and Toxicity Matrix shall be submitted to SFMTA for acceptance.

B.14.2 Toxicity

1. Those materials and products generally recognized to have highly toxic products of combustion shall not be used.

B.14.3 Electrical Fire Safety

1. Electrical equipment, wiring and apparatus shall conform to NFPA 130, Section 8, except where more restrictive requirements are imposed by this Technical Specification.

B.15 WOOD AND PANELS

B.15.1 Lumber

1. The use of wood in the car shall be limited to specifically approved applications.

B.15.2 Plymetal

1. The term "plymetal" as used in this Specification covers metal-faced plywood. All plymetal panels shall conform to following requirements:

Table 0-1 1 Plymetal Specifications

Test Conditions	**Minimum Metal to Wood Average Shear Value (or 80% Wood Failure)**
Dry shear	250 psi
Boil shear, 3 h boil, tested wet at room temperature	150 psi
Soak shear, 48 h soak wet at room temperature	150 psi
Creep or cold flow, under static load for 48 h, at room temperature	250 psi

2. In fabrication of melamine-faced plymetal panels with aluminum sheets, melamine shall be applied onto the sheet before it is laminated to the plywood core. Aluminum sheets and their fabrication shall conform to 19.15.6.

B.15.3 Plywood

1. All plywood shall be manufactured to conform with the requirements of Grade Structural I of the National Institute of Standards and Technology / APA-Engineered

Wood Association Voluntary Product Standard PS 1-95 or equivalent standard approved by SFMTA, and then stored under cover. Scarf or finger jointed panels shall not be allowed. All plywood shall be sealed with two coats of an epoxy paint on all edges and cutouts as soon as possible after fabrication. All exposed edges of panels, joints between panels, fastener heads, and openings of panels used in areas accessible to moisture shall be water-proofed and sealed with an approved coating.

B.15.4 Honeycomb Panels

1. The term "honeycomb panels" as used in this Specification refers to an assembly of honeycomb material bonded to melamine-faced metal panels or to metal panels. The materials selected for the construction of honeycomb panels shall be appropriate for the intended application and environment.
2. All "honeycomb" panels are subject to SFMTA approval.

B.15.5 Panel Contour Tolerance

1. Surfaces exposed to passengers shall not deviate from the specified contour by more than $^{3}/_{32}$-inch any 36-inch distance. The slope of any such deviation shall not exceed $^{3}/_{32}$ inches in 12 inches.

B.15.6 Melamine Faced Aluminum

1. Melamine faced aluminum panels shall be appropriate for the intended application and environment and subject to SFMTA approval.

B.15.7 Melamine Panels

1. Unbacked melamine panels may be used in the vehicle interior. The panels shall be appropriate for the intended application and environment and subject to SFMTA approval.

B.15.8 Phenolic Composite Floor Panels

1. Phenolic composite floor panels shall withstand the requirements of the intended application and environment with no visible or audible indications of delamination of the panel skin from the core, and permanent deformation of the top surface.
2. There shall be no puncture or damage to fibers of the top surface of Phenolic Composite Floor Panels.
3. There shall be no separation of any internal core from the top or bottom skin of Phenolic Composite Floor Panels.
4. There shall be no fracture of the core of Phenolic Composite Floor Panels.

B.16 FIBERGLASS REINFORCED PLASTIC

B.16.1 General

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

matrix, where the reinforcement has an aspect ratio that enables the transfer of load between fibers, and the fibers are chemically bonded to the resin.

2. FRP shall withstand the requirements of the intended application and environment without any physical deformation or structural damage.

B.16.2 Resin

1. Resin shall be of good commercial grade, thermosetting, polyester, phenolic, vinyl-ester or acrylic material.

B.16.3 Reinforcement

1. The fiberglass reinforcement shall be mat, fabric, woven roving, continuous roving, spun roving, or swirl mat.
2. The proposed glass content shall be a minimum 20% by weight.

B.16.4 Gel Coat

1. A gel coat shall be provided on all finished surfaces of FRP. The gel coat shall be resistant to scuffing, fire, weather, and cleaning agents.
2. If the surface of the FRP panel is to be painted, a primer gel coat shall be used and the part shall be painted in accordance with Section B.13. If the FRP panel does not receive paint, then the gel coat shall be pigmented to match the color scheme selected by SFMTA.
3. Finished gel coated surfaces shall exhibit no print through of the reinforcements or have any appreciable orange peel.

B.16.5 Additives

1. Antimony trioxide is prohibited as a component.

B.17 THERMOPLASTIC SHEET

B.17.1 General

1. Thermoplastic sheet shall withstand the requirements of the intended application and environment without physical deformation or structural damage and shall be resistant to all recommended cleaning solutions. Thermoplastic sheet shall be used as extruded or vacuum-formed and shall not contain plasticizers in polymer blend.
2. Thermoplastic sheet shall be homogeneous and extruded from virgin stock which does not include any regrind of vacuum formed parts. The exposed surface of this material shall conform to the color, texture, and gloss characteristics of the approved color scheme. Only UV stabilized pigments shall be used to create the specified color of the thermoplastic sheet.
3. Finished parts shall be free of waves and quilting on both sides. Degraded polymer in the sheet shall not be allowed, and if present, shall be cause for rejection of the piece. Voids, lumps, and contamination shall also be cause for rejection of parts if the defects

are larger than 0.010-in, and the population of these defects is greater than 1 defect in 4 ft^2.

B.18 SEAT CUSHION MATERIAL

1. Seat cushion fill material shall be low-smoke flexible foam constructed of inherently fire-retardant materials.
2. The cushion fill material shall have a polymerized or vulcanized homogeneous (free from foreign material), cellular structure with a porous surface and open cells.
3. The cushion fill cells shall be interconnecting and uniform in size. Cellular material may be molded in one piece or may be assembled by laminating to achieve the required thickness. Laminated cushions shall be bonded together.
4. Cushion material shall be properly cured to prevent any objectionable odor.

B.19 SEAT UPHOLSTERY MATERIAL

1. Fabrics used for seat upholstery shall be made of woven, transportation grade fabrics. The maximum fabric shrinkage shall be two percent in either the warp or fill direction.

B.20 WIRE AND CABLE

B.20.1 General

1. The Contractor's design and construction shall ensure that the minimum number of wire types and sizes shall be used in the vehicle.
2. Selection of wire sizes and insulations shall be based on the current-carrying capacity, voltage drop, mechanical strength, temperature, and flexibility requirements in accordance with applicable APTA, ICEA, ASTM, NEC, and MIL Specifications. Extra-fine wire stranding shall be utilized on applications subject to repetitive motion.

B.20.2 Conductors

1. Conductors for irradiated, cross-linked polyolefin wire shall be soft, annealed tinned copper.
2. The use of solid wire shall not be permitted except for approved wire wrap applications.
3. Wiring shall be sized for the intended load, voltage drop, installation method, and applicable codes. Wire sizes shall be in accordance with APTA-RP-E-009-98, "Recommended Practice for Wire Used on Passenger Equipment". When the free air rating is used, the Contractor shall furnish data to show that the cables will not exceed their rated temperature at the rated current. Wire ampacities shall be de-rated to meet the temperature requirements of all devices to which the wire connects. When short-time ratings, short-time overload temperatures, and thermal time constants are used to determine cable size, the parameters used shall be submitted for approval.
4. SFMTA may approve smaller wire sizes for selected applications upon submission of appropriate applicable data for justification.

B.20.3 Insulation

B.20.3.1 General Wiring Insulation

1. For all general car body wiring, the insulation shall be a flame retardant, flexible, irradiated cross-linked polyolefin material having a continuous temperature rating of 230ºF. The insulation shall be rated at 2000 volts, ac and dc, in the case of wires carrying a nominal voltage greater than 150 volts ac or dc, and rated at 600 volts, ac and dc, in the case of wires carrying a nominal voltage of 150 volts or less, ac or dc. For wire sizes AWG No. 6 and larger, the insulation material shall be formulated for extra flexibility.
2. Cross-linked polyolefin insulation shall not be permitted for use on wires connected to heater elements or any other high-temperature device.

B.20.3.2 Wire Insulation for High Temperature Applications

1. Teflon, mineral-filled, abrasion-resistant insulation may be used on wire sizes AWG No. 12 to AWG No. 28. Otherwise, high temperature insulation shall be used where wiring is connected to heat-generating apparatus, where the ambient temperature can exceed 257ºF, or where Teflon is specified as a requirement. The insulation shall be rated at 1,000 volts, ac and dc, in the case of wires carrying a nominal voltage greater than 150 volts, ac or dc, and rated at 600 volts, ac and dc, in the case of wires carrying a nominal voltage equal to or less than 150 volts, ac or dc. The insulation shall have a continuous temperature rating of 302ºF or greater and shall be in accordance with the following requirements:
    a. For wire sizes AWG No. 16 and larger: abrasion resistant Teflon (Polytetrafluorethylene – PTFE) meeting MIL-W-22759/6B or 10B, as appropriate for the voltage level used, or silicone rubber meeting AAR RP-587C. Conductors for high temperature wire AWG No. 12 and smaller shall be soft, annealed nickel-plated copper constructed in accordance with MIL-W-22759/6B.
    b. For wire sizes AWG No. 18 and smaller: abrasion resistant Teflon (PTFE) meeting MIL-W-22759/6B or 10B, as appropriate. When used for interconnecting of apparatus, this type wire shall be in bundles with a protective covering of high temperature-rated, low smoke-generating insulation.
2. For the wire insulation for high temperature applications, the Contractor shall propose insulated wire that meets the requirements of the intended application and environment and submits specifications for approval. The specific high temperature application shall include the design ambient temperature, routing, rms ampere value, worst-case ampere value, worst-case temperature rise, stranding, and insulation material.

B.20.4 Multi-Conductor Cables

B.20.4.1 General

1. Multi-conductor cables shall be constructed using wiring as described above. All conductors in multi-conductor cables shall be color coded or otherwise permanently identified as approved. Materials used in the construction of multi-conductor cables shall meet the requirements below.
2. For multi-conductor cables carrying low-voltage, high-speed, serial data, exceptions to the wiring requirements may be submitted for approval, based upon availability of wire to meet the application requirements.

B.20.4.2 Fillers

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

B.20.4.3 Tape

1. A binder tape may be employed over the assembly of conductors in multi-conductor cables if needed to assist in cable manufacture, or as required to permit the cable to function as intended in its application. The binder tape material shall be of the same (or better) temperature class as the wire insulation, and shall be of a compatible material.

B.20.4.4 Shield

1. The shield, if required, shall consist of either copper braid, concentrically served copper, or aluminum/polyester tape with a drain wire, as is appropriate for the application.

B.20.4.5 Jackets

1. The overall jacket of multiconductor cables shall be of flame retardant, cross-linked, modified polyolefin, ETFE Tefzel, or TFE Teflon to match the wire insulation and application as approved. The coupler cable shall have a jacket of low temperature arctic grade neoprene per MIL-C-13777, with a wall thickness suitable for 600 volts. The jacket shall be extruded and vulcanized over the cabled conductors, and shall be well centered, with a smooth appearance without objectionable roughness or irregularities, consistent with good industry practice.

B.21 WIRING INSTALLATION

B.21.1 General

1. All car wiring shall be in conformance with APTA RP-E-002-98, “Recommended Practice for Wiring of Passenger Equipment,” and the AAR Manual of Standards, Section F S-538, “Wiring Practice and Rolling Stock Standard”, except where

otherwise specified, and except that all wire shall be as required in this Specification. Circuit protection shall be in conformance with Chapter 2 of NFPA 70, Article 240.

2. All equipment enclosures and junction boxes, except primary power circuits, shall be fitted with terminal boards or connectors. Primary power circuits shall be fitted with compression terminals and knuckle joint connectors as described herein.
3. All wire passages into equipment enclosures junction boxes, equipment boxes shall be protected and support to prevent any damage from chaffing and rubbing on surfaces.

B.21.2 Wire Handling

1. All wiring shall be performed by qualified, experienced wiring personnel using appropriate tools for stripping insulation, cutting, tinning, soldering, harness making, attaching terminals, and other wire fabrication tasks. All wiring tools and equipment shall be used as recommended by the tool and equipment manufacturer.
2. Wire shall be protected from damage during all phases of equipment manufacture. Wire shall not be walked on, dragged across sharp or abrasive objects, kinked or twisted, or otherwise mishandled. The ends of wire shall not be permitted to lay on wet floors or other damp areas where moisture may be absorbed into the conductors.
3. When removing insulation care shall be taken to avoid nicking or breaking wire strands.
4. Longitudinal scratches in a copper strand are not considered cause for rejection.

B.21.3 Wiring Layout and Installation

B.21.3.1 Circuit Separation

1. Circuits shall be physically separated to reduce the possibility of unsafe conditions, interference, or equipment damage.
2. 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:
    a. High voltage circuits,
    b. AC circuits,
    c. Communication circuits,
    d. Battery voltage level circuits,
    e. Semiconductor gating voltage level circuits, and
    f. Conductors carrying in excess of 100 Amperes.
3. Wires which are connected in circuits with potentials differing by 50 Volts or more shall be separated by a physical barrier. The wires shall not be cabled together and shall not be placed in the same conduit, junction box, or enclosure. Where a raceway, duct, junction box or enclosure is divided into two or more distinct areas by metallic partitions, each area may be considered separately in the application of this rule.
4. Where it is impossible to avoid having wires at different voltages in the same equipment enclosure, the wires shall be physically separated, bundled, and secured

separately 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. All wiring connected to a piece of apparatus shall be insulated for the highest voltage connected. Wiring connected to transient-generating apparatus, such as unsuppressed contactor coils, shall not be run adjacent to wiring carrying signals to, from, or between semiconductor circuits, logic circuits, vital no-motion circuits, or communication circuits. In cases in which adequate physical separation is impossible, shielded wire shall be used for all conductors involved.

B.21.3.2 Wire and Cable Runs

1. Wire runs shall be continuous and unbroken between connection points, shall be supported at no greater than 2 foot spacing, and be protected at each support point against mechanical crushing and abrasion. A watertight bushing and drip loop shall be provided on all exposed cable entries. All cable bundles and wires shall be routed a minimum of 1 inch above the bottom of equipment enclosures.
2. All undercar wiring smaller than AWG No. 6 shall be run in closed wire ducts, conduits, or open wire mesh wireways in an approved manner. Wire and cable shall be secured within ducts or open wireways, including each entrance and exit point, to prevent chafing movement. Wire ducts and conduits shall be of waterproof construction. Permanently retained watertight strain relief bushings, with insulated throat liners, of an approved design, shall be used at locations where wires, cables or harnesses enter or exit conduit, ducts, apparatus and equipment enclosures. In addition, strain relief bushings on equipment enclosures shall include a permanently retained O-ring type seal.
3. Lead wires to resiliently-mounted electrical apparatus shall be carried in conduit to a point as close to the apparatus as possible. The length of the leads between the end of the conduit and each piece of apparatus shall be as approved. Short runs of cables or harnesses entering or leaving conduit and apparatus shall have an approved guard mounted to the car body to protect the wires from mechanical damage. Lead wires to solidly-mounted, electrical apparatus and equipment enclosures shall run in conduit connected to the apparatus or enclosure.
4. All wiring routed from enclosed areas of the carbody to areas exposed to the elements (including underframe and roof areas) or between interior levels shall be run in ducts or conduit. Wiring, even if enclosed in loom, must not be run through partitions without suitable bushings being provided at such points of passage.
5. Cables shall be laid in place with sufficient slack at the bends so that cables shall clear the inside bend surface of the wireway/wire duct.
6. All wire and cable shall be free of kinks, insulation damage, insulation abrasions, and nicked strands. Wire installation shall not be subject to accumulations of water, oil, or other foreign matter.
7. Wires or cables shall not pass through or over the battery compartment and shall not pass over heat generating equipment such as acceleration and braking resistors, even if the wires or cables are in conduit.

8. Exposed harnesses, short cable runs or harness entering or leaving exposed raceways shall have approved, fire-resistant flexible dielectric sleeving over the raceway edges and grommet-type insulation of any penetration holes. Wiring shall be retained to the sleeving with tie-wraps.

B.21.3.3 Cable Cleating and Support

1. All cable and wiring exiting wireways/wire ducts, or that which is not installed in conduit, shall be cleated. In no case shall nylon wire ties be used as the means of supporting the weight of wire bundles and cables. Cables shall be cleated and bushed when passing through bulkheads and structural members. The Contractor shall minimize the quantity of different configuration cable cleats.
2. AWG No. 6 or larger insulated wire may be cleated in place without conduit, duct or open wireway. However, in the areas over the truck, in the wheel wash and not protected by underfloor-mounted equipment, the wire shall be mechanically protected by an open mesh, expanded metal or other type of approved guard. The guard may be attached to the bottom of each cleat with the cleat clamping bolts or other approved arrangement.
3. Cleats shall grip each cable individually and firmly, but without causing any damage to cable insulation, including cold flow of the insulation. Each cable in the cleat shall have its own cutout sized to the correct wire diameter. The cleat openings shall be chamfered to 45 degrees. Cleated cables shall be routed and supported such that they cannot, under any combination of forces and car movement, touch each other or any other part of the car, except the cleat cushioning material.
4. Wire and cable runs shall be continuous and unbroken between terminations and shall be supported at not greater than 24-inch intervals in ducts, open wireways or when cleated. The wire shall be protected at each support point against mechanical crushing and abrasion.
5. Concealed wires, such as within conduits and wire ducts, shall be such that wires may be replaced or added to without the removal of other than access panels. It shall not be necessary to disconnect or disassemble conduit to accomplish this task.
6. Wiring run in loom shall not be carried over a potential chafing hazard. Wires entering any removable box shall be harnessed and secured to facilitate removal of the box.
7. All wires and cables shall be fully protected against any contact with any surface other than that designed specifically to support or protect them. This applies to all current carrying wires, cables or buses on the vehicle.

B.21.3.4 Wire Securement and Termination

1. All wiring shall be secured and protected against movement, chafing, and any contact with conductive, sharp, or abrasive objects including the inside surfaces of wire runs.
2. All wiring shall be located and secured such that normal equipment motions, maintenance access, heat sources, and the environment do not damage or reduce the life of the wiring.

3. Junction boxes, with terminal boards, shall be used, as required, for wire terminations. Exterior junction boxes shall be weather tight.
4. Wire and cable dress shall allow for sufficient slack at equipment terminals to provide for movements induced by shock and vibration, equipment shifting, alignment, cover removal and component replacement. Sufficient lengths shall be provided at points of termination for additional re-terminations without applying tension to the wire and without splicing the wire, as follows:
   a. AWG No. 10 and smaller - Three re-terminations
   b. AWG No. 8 and larger - Two re-terminations
   c. A drip loop shall be provided on all exposed wires and cables to prevent fluid runoff into connected equipment.
5. Spare wires, which are part of a wire harness, shall be bundled separately inside of the equipment box to which the harness is being terminated. Spare wires shall have enough length to reach any location within the box, including sufficient slack for the required number of re-terminations. The spare wire "break-out" bundle may be ty-wrapped to the main harness, but shall be easily removed from the main harness without disassembling it. The ends of the spare wires shall be insulated against inadvertent contact with any nearby conductive surfaces or terminals.
6. Wire tying devices shall be of such material and construction that they shall adequately retain the wires for the life of the wiring and shall be resistant to ozone and ultraviolet light. Wire and cable ties shall be trimmed and located to eliminate any hazard to personnel from sharp edges. Wire tying devices shall be snug, but shall not be so tight as to cause indentation and cold flow damage to the insulation. Wire tying devices shall be mechanically fastened to a permanent structure. Adhesive-installed mounting bases shall not be used for ties or for cable support.
7. All wire bundles and cables within an enclosure shall be supported by the use of tape rails, shall be spaced away from the equipment box structure, metal edges, bolt heads, and other interference points, and shall have electrical clearance from the covers, regardless of the insulation properties of covers. Wire bundles shall be located above or alongside the apparatus rather than at the bottom of the box wherever possible. In all cases, wire shall be a minimum of 1 inch above the bottom of the box, unless otherwise approved by SFMTA. Wire entry into control or junction boxes shall not be permitted through the bottom of the box.
8. All jumpers, jumper heads, and jumper receptacles shall be sealed in an approved manner to prevent the entry of water at any operational speed of the car.
9. Any wiring needed to calibrate and test car functions shall be a part of the permanent car wiring to enable SFMTA to conveniently maintain the equipment. This wiring shall terminate in connectors in the respective control groups and cabinets.
10. Wire and cables that are subject to high currents in fault conditions or normal operation must be secured against secondary damage due to the high magnetic forces that are developed. Propulsion inverter circuits are a typical example. This includes damage to bus bars or devices to which the cables terminate.

B.21.3.5 Circuit Shielding

1. Wire shields used in trainline circuits shall be continuous up to the car's electrical coupler contacts, including contacts of the jumper cable connector at the intermediate couplers. The wire shields shall be connected through all applicable connectors and junction boxes. Circuits shall be categorized. Shields contained in one circuit category shall not be interconnected with shields contained in another category. Shields used to protect against interference shall not carry signal current.
2. Shields on low-level signal wires shall not be interconnected with shields on high-level signal wires in the same category. Each group of shields (other than at the electric couplers, including the jumper cable connectors at the intermediate coupler) shall be carried through on a connector pin or pins, or on terminal strips which shall be in the immediate proximity of the categorized group of circuits. Loops due to interconnections of shields shall not be permitted.
3. Coaxial cables used as constant impedance transmission lines shall be terminated as dictated by the circuit termination design and shall not be considered to be shielded conductors. Tri-axial cables may be used as coaxial impedance transmission lines with the outer conductor employed as an RF shield.

B.21.4 Marking and Designation

1. The Contractor shall devise a wire and terminal marking and designation system that shall coordinate all electrical circuits in the car into a unified system. The system shall identify all wiring, including circuit return wiring, and terminals according to their respective circuit function(s) and shall accurately correlate these designations with the car schematic diagrams. Each circuit shall be individually designated from point to point. Common designations for return circuits are not permitted.
2. Each wire and cable shall be permanently and legibly marked along its entire length on the outer surface, the manufacturer's identification, conductor size, temperature rating, and voltage rating. For wire size 1/0 and larger, stranding shall be given in addition to the other parameters. A circuit designation shall remain unchanged when it goes through a terminal strip or junction box stud regardless of how many wires of that circuit are common to that point. A Wiring Plan shall be submitted for SFMTA acceptance and include documentation for provisional spare wiring.
3. Wires in multiple-conductor cables shall be color-coded.
4. Wire markers shall meet the adherence and solvent resistance requirements as specified by MIL-M-81531 Sections 3.4.2 and 3.4.3, and shall withstand all combinations of ambient and equipment temperatures. Hand printing is prohibited.

B.21.5 Pulling Compound

1. Pulling compound shall be non-conductive, non-hygroscopic, non-odorous, shall not support bacterial activity, and shall not attract vermin.

B.21.6 Solder

1. Solder shall be in accordance with ASTM B32, Grade Sn60. A flux of non-corrosive type shall be applied immediately before soldering.

B.21.7 Primary Power Wiring

1. The primary power feed shall be installed without taps or splices from the High Speed Circuit Breaker (HSCB) directly to the primary power switch. This wire shall be run in a conduit containing no other wiring.
2. Primary power wiring installed within the car body shall be run in conduit or wire-ways. Conduits or ducts that penetrate the car body shall be terminated in a waterproof entrance box or with a waterproof fitting. Primary power wiring, except for heater wiring, shall not terminate within the car body.

B.21.8 Articulation Connections (if equipped)

1. Flexible hoses, wiring and cabling routed across the articulation shall be run in ducting with non-conductive inserts. The routing shall minimize excess length and unnecessary flexing. All primary power wiring shall be run on the vehicle roof. Low voltage wiring may be run below or above the floor line, or on the roof.
2. Quick disconnect cable connectors shall be provided for low voltage circuits and high voltage circuits on both sides of the articulation. The quick disconnect arrangement shall be: A bracket on both A and B car ends holding bulkhead connectors, located as either as close to the centerline as possible or on the sides to allow cables to droop between the bellows and car enclosure. A quick disconnect connector shall be provided on both ends of the jumper cables. A cable clamping arrangement shall be provided to protect the cable motion from placing stress on the connectors.

B.22 WIRING CONNECTIONS

B.22.1 Terminal Boards & Terminal Points

1. As used in this document, the term “terminal board” refers to all devices commonly called terminal blocks, terminal strips, terminal studs, or similar items to which wires are connected.
2. Each terminal board shall have a minimum of 10%, 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.
3. The terminal board insulation shall be a strong, high temperature rated, tracking resistant material that is not brittle.
4. Adequate space shall be provided to permit connecting wire terminals with standard tools.
5. A maximum of four terminals shall be connected to any single terminal stud, provided that there is no interference between terminal barrels and sufficient threads protrude

beyond the nut. On terminal boards, the wiring shall be arranged so that no more than two terminals are connected to a stud, from each side of the terminal board.

6. On compression clamp terminal boards, a maximum of two terminals shall be connected to any one binding terminal. All connected wires shall be terminated with mechanical crimp type terminals as specified in Section B.22.2.
7. Threaded studs shall have a minimum of 2-1/2 threads exposed beyond the final nuts. Adequate space shall be provided to permit connecting wire terminals with standard tools. All terminals shall be properly torqued to assure sound connections. Spacers shall not be used.
8. A maximum of two terminals shall be connected to any one binding screw. A maximum of four terminals shall be connected to any one threaded stud, provided that there is no interference between terminal barrels. On terminal boards, the wiring shall be arranged so that no more than two terminals are connected to a stud, from each side of the terminal boards.
9. Terminal blocks which utilize a spring clamp to hold the wire may be used for low voltage circuits. Each terminal block shall be properly identified with a permanent marking and each assembly shall be secured to the mounting (DIN) rail by end clamps which incorporate metallic hardware. All wires AWG 12 and smaller shall receive a ferrule.
10. Jumpers between terminal board points shall be brass or plated steel. Wire jumpers between adjacent terminals of terminal boards shall not be permitted.
11. An approved permanent marking strip on each terminal board shall be provided and attached adjacent to the wire junction point to identify the wires attached thereto and/or the wires connected to terminal boards shall have the terminal point location printed on the wire.

B.22.2 Wire Terminations

1. Terminals and connections used throughout the car shall be the mechanical, solderless, crimp type. The Contractor shall minimize the total number of crimping tool types needed for all crimp connections.
2. Terminals and connections shall be attached to the wiring with proper crimping tools and dies as recommended by the manufacturer. For components that do not accept ring tongue or Faston terminals, appropriate alternate terminations such as ferrules, locking forks or quick disconnects may be used subject to approval by the SFMTA. Corrosion protection shall be provided for all base materials.
3. Conductors subject to motion relative to the terminal shall be protected by suitable means to prevent breakage of the conductor at or near the terminal. Sufficient slack shall be provided in all wires and cables to prevent breaking or pulling out of bushings and terminals. A maximum of one wire shall be crimped in any one terminal.
4. Wherever several wires are connected to terminals of a terminal strip on a device which is removable from the car for maintenance, the wires shall be terminated, with double ring terminations which shall be screwed to an insulating fanning strip which

shall serve to keep the terminations in the correct relative locations while removed from the device.

B.22.3 Power Cable Terminations

1. Power cables shall be terminated with compression terminals. Cable slack shall be provided to preclude breaking or pull-out from bushings or terminals and to allow two terminal changes. Cable conductors shall be clean prior to installation of terminals. Compression terminals shall be applied using tools and procedures recommended by the terminal manufacturer for that purpose.
2. 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.
3. Power wire terminals on the traction motors shall be a waterproof.

B.22.4 Cable Connectors

1. All cable connector shall meet the requirements of the intended application and environment.

B.22.5 Quick-Disconnect Terminals

1. Quick-disconnect terminals shall be utilized to facilitate maintenance and inspection. They shall provide positive terminal engagement and be shock and vibration proof. All terminals shall be provided with insulation equal to that of the wire.

B.22.6 Grounding Return Connections

B.22.6.1 Grounding

1. Grounding connections to the car body and equipment shall be made through copper pads of an adequate area, silver soldered or brazed. Anti-corrosive grease shall be applied over the connection.
2. Braided, strap-type leads shall be used where there is relative motion between the two items being connected.
3. Low voltage and high voltage circuits shall not be grounded to the same ground.

B.22.6.2 Bonding

1. The bonding method employed shall not produce a DC resistance in excess of 0.0025 Ohms, or more than 0.025 Ohms at 150 kHz for any applied AC voltage. Grounding and bonding jumpers, and brazed shunt straps shall be “extra-flexible”.

B.22.7 Wire Splicing

1. Wire splicing is prohibited.

B.23 CONDUIT

B.23.1 General

1. Where possible, all conduit shall be rigid aluminum alloy or galvanized rigid steel as described below. Flexible conduit may be used where necessary.
2. All conduit ends shall be deburred inside and out to remove sharp edges and all pieces shall be cleaned before installation to remove filings and other foreign material.
3. All conduit bends and offsets used shall be made by the use of special forms or tools and shall have the largest radius possible so that wires can be drawn in by, and without, the use of tackle or power.
4. Conduit shall be securely clamped with all runs electrically grounded to make a continuous ground. Electrical continuity of joints shall be provided by the use of conductive joint compound.
5. All conduit shall be arranged to prevent moisture traps and shall drain toward control boxes.
6. Conduit fittings that mate with wire ducts, enclosures or junction boxes shall be fitted with resilient seals.

B.23.2 Aluminum Conduit

1. All threads shall be covered with an oxidation inhibiting compound.
2. Aluminum fittings shall be used to assemble aluminum conduit. Elbows, nipples and couplings shall be made of the same grade of aluminum and alloy as that employed in the straight length of conduit.

B.23.3 Steel Conduit

1. Steel conduit shall be mild steel in standard lengths with threaded ends and hot-dipped zinc-coated exterior and interior surfaces. It shall be free of burrs and projections, circular in cross-section, of uniform wall thickness.
2. Steel fittings shall be used to assemble steel conduit. Elbows, nipples and couplings shall be made of the same grade of steel as that employed in the straight length of conduit.

B.23.4 Flexible Conduit

1. Flexible conduit shall have a waterproof, abrasion resistant covering. The flexible covering shall not contain polyurethane or PVC.
2. Fittings for flexible conduit shall be as supplied or recommended by the flexible conduit manufacturer.

B.24 WIRE DUCTS

1. Wire ducts shall be fabricated from galvanized mild steel or stainless steel.

2. Steel ducts and covers shall be galvanized after all welding, cutting and drilling operations. The inside of steel shall be primed and painted with white paint. Exteriors and covers shall be painted according to the color scheme. Seals shall not be painted.
3. Wire ducts shall incorporate wire support hardware sufficient to support wiring every 24 in or less, and if required, rigid barriers for circuit separation.
4. Undercar, roof, and other exterior wire ducts shall have waterproof covers with resilient seals. The covers shall be stiffened such that the seals are compressed evenly over the seal length when fastened. Undercar duct covers shall be on the bottom of the duct.
5. Interior wire duct covers need not be sealed.
6. All wire ducts shall be located such that it will be possible to remove covers and reach the wiring within.
7. The sum of the cross-sectional areas of all conductors contained at any cross-section of a wire duct shall not exceed 50 percent of the interior cross-sectional area of the wire duct.

B.25 JUNCTION BOXES

1. Junction boxes are defined as enclosures used only for the termination of wiring and do not contain electrical equipment.
2. All exterior and interior junction boxes shall be constructed to NEMA 4 and NEMA 12 standards respectively and as described below. Where conflicts exist, this document shall prevail.
3. The interior of all junction boxes and covers shall be primed and painted. Seals and cover hardware shall not be painted.
4. Terminal boards or other equipment shall not mount directly to the enclosure. All equipment shall mount to rails, brackets or standoffs fastened to the enclosure. No equipment shall be mounted to the enclosure bottom or within 1 in of the bottom.

B.26 ELECTRICAL DEVICES AND HARDWARE

B.26.1 Contactors and Relays

1. Contactors and relays shall comply with the requirements of MIL-R-6106 (for ratings of 10 Amperes or greater) and MIL-R-5757 (for ratings of less than 10 A) but need not be qualified to these documents if all of the following requirements are met:
    a. The device is service proven in the exact same application.
    b. The device is service proven in transit service.
    c. All other requirements of this Specification are met.
    d. SFMTA approves of this application.
2. All devices shall be constructed and utilized in a fail-safe manner; that is, all failures shall be in a direction so that neither the passengers, the crew nor the equipment are placed in jeopardy.
3. All devices shall be installed so that they are fully accessible for inspection, repair-in-place, or removal and replacement.
4. All contactor terminals shall be fully accessible for trouble shooting purposes.
5. Contactors and relays shall incorporate means of visually determining whether they are picked up or dropped out.
6. Relays on printed circuit boards or within electronic assemblies are exempted from the requirement for a visual indication.
7. There shall be a maximum of two wire terminations on any one contact of the device.
8. The coils of all devices shall be suppressed to protect the low-voltage network from generated transients.
9. Contact tips of the devices shall meet or exceed the manufacturer’s recommended contact tip rating.
10. Contactor installation shall be such that the arc spray is directed by an arc chute away from ground and any other electrical devices proximate to the contactor.
11. All contactors shall be constructed so that the main contact tips make and break with a motion (wipe) that prevents deposits and pitting.
12. All time delay relays shall be of the R-C delay or solid state type. No mechanical or pneumatic time delay devices shall be permitted.

B.26.2 Switches

1. Under no circumstances shall poles of switches be placed in parallel in order to carry currents in excess of the contact pole rating given by the manufacturer.
2. Switches shall be provided with a “keying” feature so that after installation, the body of the switch is constrained from mechanical rotation.
3. There shall be a maximum of two (2) wires connected to each terminal of the device.
4. Switches shall be individually replaceable without disconnecting or removing anything other than the mounting fasteners and electrical connections of the switch to be replaced.

B.26.3 Circuit Breakers

B.26.3.1 General

1. All circuit breakers provided shall be extremely rugged and shall meet the requirements of the intended application and environment.
2. The “ON”, “OFF”, and “TRIPPED” positions of all circuit breakers shall be permanently marked on the handle or the case of the circuit breaker. The circuit breaker, when tripped, shall assume a distinct position between the “ON” and “OFF” positions to permit determination of the fact that it has been tripped by either its over-current or shunt trip elements. All circuit breakers shall be mounted in the vertical direction with the “ON” position up.
3. Each circuit breaker pole shall be equipped with adequate means of arc extinction to prevent flashover.
4. Circuit breaker current rating shall be clearly and permanently marked and shall be completely visible after installation.

B.26.3.2 High-Voltage Circuit Breakers

1. All high voltage circuit breakers shall be devices with not less than 3 poles connected in series.
2. The trip elements shall be thermal-magnetic, or magnetic, connected in series.
3. The circuit breaker handle shall protrude from the circuit breaker panel cover sufficiently to be manipulated in all positions.

B.26.3.3 Low-Voltage Circuit Breakers

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

B.26.4 Fuses

1. Fuses shall be used only where the use of circuit breakers is not technically feasible.
2. High voltage fuses shall be mounted in totally enclosed, dead front fuse holders, with no exposed high voltage connections. The fuse shall be extracted from the circuit when the fuse holder is opened and the exposed fuse shall be safely isolated from any circuit connection.

B.26.5 Buss Bars

1. Current densities, other than at joints, shall not exceed 1,000 Ampere per square inch, and in any case shall not exceed a value which would cause a bus bar temperature rise greater than 96ºF. Current densities in joints shall not exceed 150 Ampere per square inch.
2. Bus bars shall be properly brazed together at joints unless bolted connections are found to be absolutely necessary for maintenance purposes and are approved. The

overlap at bus bar joints shall be no less than 10 times the thickness of the bus material.

3. Except for connection areas, bus bars shall be safety-insulated, using a high-dielectric powder coating, heat shrink tubing or other approved means. Tape is not acceptable. Bus bars that are behind insulating panels are exempt from this requirement.

B.26.6 Capacitors and Resistors

1. Capacitors shall be derated 20 percent for voltage based on the nominal supply voltage and maximum case temperature.
2. Except for braking power resistors, all resistors shall be derated 50 percent for power dissipation.

B.26.7 Transformers and Inductors

1. Transformers and inductors shall be derated 10 percent for current.

B.26.8 Switch, Circuit Breaker, and Fuse Panels

1. Each switch and circuit breaker panel shall carry the necessary apparatus, arranged to be easily accessible to connections and shall prevent operating or maintenance personnel from coming in contact with live parts when operating the switches or circuit breakers. Furthermore, all live portions of the protected circuitry shall be completely concealed so that no danger of electrocution or shock exists from the touching of the panel or any appurtenances or devices mounted thereto.
2. All switches, breakers, fuses, and indicating lights shall be provided with a nameplate of raised or recessed lettering on the dead front, clearly identifying the circuit which each controls and its circuit designation. The dead front panel shall conform to NFPA 70, Article 384. The dead fronts shall be made of moisture-proof, electrically insulating, laminated phenolic or fiberglass, of approved quality suitable for switchboards. Asbestos shall not be used.
3. The panel shall be secured by captive fasteners and shall be configured for easy removal so that maintenance and repair action is not impeded.

B.27 SEMI-CONDUCTORS

B.27.1 General

1. Semiconductors shall be selected to withstand all continuous and transient voltage and power demands present in the circuit application without damage or reduction in life. All circuit designs shall provide for the presence of high current switching equipment on the vehicle and the resultant induced voltages and currents in electrical equipment.
2. Discrete semiconductors shall have the following minimum voltage breakdown ratings:
    a. Semiconductors, except diodes (see below), operated from the battery supply, or those connected to trainlines, shall have minimum breakdown ratings of 4

times the maximum achievable circuit voltage. Suppression devices shall be provided as necessary to protect the devices and limit the circuit voltage.

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

c. All discrete semiconductors operated from inverters or other isolating devices shall have a minimum breakdown rating of 2 times the maximum circuit voltage, except where specifically detailed otherwise. Suppression devices shall be provided as necessary to protect the devices and limit the circuit voltage.

3. All Gallium Arsenide and similar optical semi-conductors shall be rated for operation over the temperature range of -40°F to +185°F.
4. Germanium semiconductors shall not be used.

B.28 PRINTED CIRCUIT BOARDS

B.28.1 Marking

1. All circuit boards shall be labeled with a part number and descriptive nomenclature.
2. Integrated circuits and other multi-terminal devices shall have an index mark on the component side of the board, visible with the component inserted, to indicate proper keying and insertion; the first pin on all IC packages shall be identified on the wiring side of the board.

B.28.2 Component Mounting

1. Components shall be fastened to the board in such a manner as to withstand repeated exposure to shock and vibration. Power resistors shall be mounted on standoffs so that the resistor bodies do not contact the board, spaced far enough away from the board so that resistor-produced heat will not discolor or damage the board.

B.28.3 IC and Device Sockets

1. IC and device sockets are prohibited except for components that must be removed for reprogramming or initial calibration procedures or devices that are available only in mounting in sockets. All other components shall be soldered in place.

B.28.4 Conformal Coating

1. Both sides of assembled printed circuit boards shall be coated with a clear insulating and protective coating material conforming to MIL-I-46058 latest revision, or approved equal.

B.28.5 Keying and Interlocks

1. All circuit boards mounted in a rack shall be keyed to prevent insertion into the wrong location.

B.28.6 Circuit Board Connectors

1. Printed circuit board connectors shall be heavy duty, high reliability, 2-part type with a history of successful service in rail applications.

B.28.7 Enclosures and Circuit Board Hardware

1. All circuit boards that are rack mounted shall plug into racks containing the mating half of the circuit board connector.

APPENDIX C – PROGRAM MANAGEMENT AND QUALITY ASSURANCE

This section is intended as an example of standard program management and Quality Assurance requirements. It is SFMTA's intention that, at the Proposal stage, each bidder proposes its own criteria, where different, for approval. Upon completion of negotiations with the winning bidder, the agreed content will form Section 20 of the Specification document.

C.1 GENERAL

C.1.1 Program Management

1. Program management shall be sufficiently comprehensive to enable meeting, with a high degree of confidence, the requirements of this Technical Specification and meet the delivery of the agreed contractual schedule and cost.
2. Specification shall be conformed to agreements reached during pre-Contract negotiations so that it contains requirements consistent with Contractor and SFMTA understandings at Contract signature.
3. Contractor shall make available to the SFMTA's technical representatives the physical facilities and the details of the designs as they progress in order to take maximum advantage of the intended approach.

C.1.2 Program Management Plan

1. A Management Plan shall be developed, negotiated, agreed to during pre-contract negotiations, and included in the Contract.
2. The Management Plan shall include Preliminary Design Review (PDR), Final Design Review (FDR), required audits, and shall also include, but shall not necessarily be limited to:
    a. The agreed organization chart including names and a definition of the responsibilities and qualifications of all personnel therein, for the SFMTA and Contractor. As appropriate, location of SFMTA and Contractor staff shall be identified at:
        i. Design facilities,
        ii. Manufacturing facilities,
        iii. Assembly facilities,
        iv. Project installation facility.
    b. The internal methods, communications, correspondence coding system, and correspondence control to be used to monitor, oversee, and manage the:
        i. Requirements,
        ii. Schedule,
        iii. Program changes,

iv. Sub-contracts,
v. Purchase orders,
vi. Material procurement,
vii. In-service support,
viii. Warranty,
ix. Systems assurance analysis,
x. Tests,
xi. Demonstrations.

c. A Master Program Schedule (MPS) in Critical Path Method (CPM) format showing key milestones and events, and the details of Program design, test and inspection, manufacturing, and delivery activities.
d. Necessary points of required input from the SFMTA shall be included in the Schedule.
e. Schedule shall show drawings, procedures, functional descriptions, and other documents required to be prepared by the Contractor, and reviewed and accepted by the SFMTA.
f. Payment milestones shall be shown on the Schedule.

C.1.3 Project Documentation System

1. Correspondence control shall be administered by a mature, proven Project Correspondence System, which shall:
   a. Maintain electronic copies of all correspondence,
   b. Support assignment of responsible responders,
   c. Support e-mail for:
      i. Document announcement,
      ii. Response assignment,
      iii. Due date reminder,
   d. Provide the ability to search and generate reports.
2. Each submittal shall be coded to allow tracking in the system throughout the process of review, from posting by the Contractor through the process of review/approval by the SFMTA.
3. The initial posting by the Contractor shall provide a brief description of the purpose of the submittal along with a list of:
   a. Drawing titles,
   b. Document titles,
   c. Document numbers,
   d. Revisions for drawings,
   e. Data included in each posting.

4. The System shall maintain a record of Contractor and Sub-contractor drawing and document status.
5. The CDRLs listed below are meant to be a guideline for proposers to consider. The reference section provides the location within the technical specification that further information can be found:

Table C-1 2 Contract Deliverables Requirements List

Description	**Reference in Technical Specification**
Interface Control Plan	1.4
Test Plan	1.4.2
Interoperability & Compatibility Report	1.4.3
ADA Compliance Certification	2.2.6
Civil Interfaces PDR	2.2.6
Civil Interfaces FDR	2.2.6
Vehicle Dynamic Clearance Envelope Analysis	2.2.6.2
Vehicle Dynamic Analysis	2.3.2
Traction Motor Fordability Analysis	2.3.4
Noise Control Plan	2.5
Noise Control Analysis	2.5
Ground Borne Vibration	2.5.5
Ride Quality	2.5.8
Curving and Derailment Safety	2.5.9
Stability Analysis	2.5.10
EMC Plan	2.6.2
EMC Emissions Report	2.6.7
EMC Susceptibility Report	2.6.7
Reliability Analysis	2.8.1
Maintainability Program Plan	2.9.1
Lifting and Jacking Design	3.1.2
Welding Procedures & Welder Qualifications	3.1.5.2
Water Drainage Scheme	3.1.6
Carbody Fatigue Analysis	3.2

Draft Gear Absorption Energy Absorption Analysis and Test Results	4.2.1.4
Cab Area Human Factor Compliance Analysis	5.2.1
Car Level Thermal Load Analysis	7.1
Air Flow Design Calculations	7.2.2.1
Emergency Lighting Design Report	8.3.1
Exterior Lighting Design Report	8.3.2
Short Circuit Analysis	9.1
Battery Sizing Analysis	9.2.5
Propulsion Performance and Duty Cycle Rating	10.1.2
Event Recorder List of Monitoring	14.1.1
Software and System Documentation Requirements Document	18.1.1
Software Deliverable	18.1.1
Vehicle Production Photographs	20.1.3
Component, Subsystem and Whole CAR FAI Procedures	20.1.6.3
Component, Subsystem and Whole CAR FAI Reports	20.1.6.3
Requirements Traceability Matrix	21.2.1
Reliability Program Plan	21.3.10
Maintainability Demonstration Test Plan	21.3.11
System Safety Program Plan	21.3.5
Safety Analysis	21.3.7
Preliminary Hazard Analysis	21.3.7.1
Failure Modes Effects Analysis	21.3.7.2
Sneak Circuit Hazard Analysis	21.3.7.3
Operating and Support Hazard Analysis	21.3.7.4
Fault Tree Analysis	21.3.7.5
Hazard Mitigation Traceability Matrix	21.3.7.6
Fire Safety Analysis	21.3.8
Reliability Program	21.3.10
Reliability Demonstration Test	21.3.12
Manuals Program Plan	22.2.1
Design Style Guide	22.2.1.1

Manuals	22.2.1.2
Running Maintenance Manual	22.2.1.3
Heavy Repair and Overhaul Manual	22.2.1.4
Illustrated Parts Catalogs	22.2.1.5
Integrated Vehicle Level Schematics and Description	22.2.1.6
As Built Drawings	22.2.2
Car History Book Format	22.2.3
Car History Books	22.2.3
Trainings Program Plan	22.2.6
Training	22.2.6
Training Mock-up	22.2.6.5
Carbody Stress Analysis	C.2.4.1
Carbody Stress Analysis Test Plan	C.2.4.1
Carbody Finite Element Analysis	C.2.4.1
Carbody Stress Analysis	C.2.4.1
Carbody Finite Element Model	C.2.4.1
Carbody Linear Elastic Analysis Validation	C.2.4.1
Carbody Crashworthiness Analysis Report	C.2.4.1
Truck Stress Analysis Report	C.2.4.1
Subsystems PDR	C.2.4.1
Subsystems FDR	C.2.4.1
Subsystem Qualification Test Procedures	C.2.4.1
Subsystem Qualification Test Reports	C.2.4.1
Vehicle Qualification Test Procedures	C.2.4.1
Vehicle Qualification Test Reports	C.2.4.1
Pre-shipment Test Procedures	C.2.4.1
Production Acceptance Test Procedures	C.2.4.1
Vehicle Acceptance Test Procedures	C.2.4.1
Quality Assurance Manual	C.2.7.1
Radiographic Inspection Reports	B.5.2
Casting Test Reports	B.5.2
Pressure Vessel Test Reports	B.11.5

Smoke, Flame & Toxicity Matrix	B.14.1
Spare Wiring Descriptions	B.21.4
Wiring Plan, Identification System, Connections and Terminations	B.21.4
Conduit & Cable Run Plans	B.21.4

C.2 SPECIFIC REQUIREMENTS

C.2.1 Interface with Sub-contractors, Designers and the Contractor

C.2.1.1 General

1. The Contractor shall ensure that all designers and Sub-contractors are informed of all specified requirements and that appropriate engineering management tools are utilized to coordinate and provide communication between the designers of interrelated systems.
2. The Contractor shall have all relevant designers and Sub-contractors available when required for:
    a. Meetings,
    b. Production problems,
    c. Testing,
    d. Resolution of design deficiencies,
    e. All other similar situations.
3. During all phases of this project, the SFMTA shall have access to all designers and Sub-contractors through coordination with the Project Manager.
4. The Contractor shall coordinate all sub-contractor design and installation activities.

C.2.2 System Integration

C.2.2.1General

1. The Contractor shall actively employ system integration principles throughout the:
    a. Design,
    b. Production,
    c. Test phases of the Contract.
2. The practiced principles will control and coordinate the interfaces among the vehicle’s systems as well as uphold the requirements between the vehicle the operational and the maintenance systems.

C.2.2.2 Systems Integrator

1. The Systems Integrator shall have an understanding of the interaction of all vehicle systems and parameters as well as possess experience in coordinating interface requirements.
2. The Systems Integrator shall participate in the design review process.

C.2.3 Meetings

C.2.3.1 Project Meetings

1. Jointly led project meetings, including pre-production, periodic, and special meetings, shall be conducted according to Schedule throughout the progress of the work.
2. Agendas for the meetings may include any topics that the Project Managers determine to be relevant to the project such as:
    a. Discussions of progress observations,
    b. Problems,
    c. Conflicts,
    d. Production schedules,
    e. Delivery schedules,
    f. Sub-contractor fabrication,
    g. Quality standards,
    h. Design review,
    i. Contract modifications.

C.2.3.2 Kick-Off Meeting

1. The first project meeting shall be within 30 calendar days after NTP for the purpose of discussing with the Contractor all essential matters pertaining to the successful prosecution and completion of the Work.
2. At this meeting, as a minimum the following shall be accomplished:
    a. Introduce key personnel of the Team,
    b. The Contractor shall submit for joint review document coding schemes, Schedule and monthly report format,
    c. Confirm project control methodology and plans for initial activities before the start of formal progress reporting,
    d. Confirm that the Contractor is familiar with SFMTA's intended operations and maintenance environment,
    e. Identify the early information needs and decisions required by the Contractor from the SFMTA,
    f. As an option, product familiarization presentation for the benefit of SFMTA's operations and maintenance staff to afford them an opportunity to comment on the vehicle from their perspective,

   g. SFMTA alerts Contractor to external pressures that will drive SFMTA expectations.

C.2.3.3 Schedule-Based Project Management Meetings

1. Meetings shall be held between the Contractor and the SFMTA on a regular basis for the purpose of reviewing project progress and other activities.
2. An agreed number of days prior to a project review meeting, the Contractor shall submit the agenda and a data package covering information to be addressed in the meeting.
3. These meetings are intended to serve as a forum to discuss design problems and issues, to answer questions raised by the agency, the Contractor or its Sub-contractors:
   a. To discuss contractual matters,
   b. Any other topics that the Project Manager determine to be relevant to the project to review schedule and payment issues,
   c. To witness tests and discuss their results,
   d. To review:
      i. Design,
      ii. Fabrication,
      iii. Assembly status,
      iv. Vehicle weight status.
4. The Contractor shall ensure that persons knowledgeable in the topics to be discussed, including appropriate Sub-contractors, are present as required at these meetings.
5. SFMTA shall ensure that SFMTA Team members with authority to make approval decisions about subjects discuss and attend each meeting as appropriate.

C.2.3.4 Progress/Design Review Meeting Reports

1. Meeting minutes of Progress/Design Review meetings shall be recorded alternately by the SFMTA and the Contractor and will be circulated among the attendees for agreement.
2. Draft minutes shall be provided within 5 working days after each meeting.
3. Attendees shall respond with comments or acceptance within 5 working days of receipt. If no comments are received during that time, full concurrence will be assumed.
4. The Contractor shall submit for SFMTA approval monthly progress reports that assess actual progress against planned progress. The report shall include the following information:
   a. An updated Master Schedule showing progress as of the reporting date,
   b. A schedule report listing all activities, elapsed and remaining duration of activities, early start/early finish dates, late start/late finish dates, predecessor and successor activities, and float,
   c. A narrative report that, as a minimum, describes:

i. Work accomplished during the reporting period,

ii. Percent of design, manufacturing, delivery, testing, and system support elements completed during the reporting period, and percent of overall work completed,

iii. Delays incurred during the reporting period, their causes and effects, and the corrective actions proposed or taken to mitigate those delays,

iv. Changes in activity duration,

v. Changes in activity logic,

vi. Failure statistics, along with corrective actions taken,

vii. Changes in the agency approved design plans and layout, any other topics that the Project Manager determine to be relevant to the project,

viii. Changes in vehicle construction methodology and consistency,

ix. Updated drawing list,

x. Updated vehicle weight estimate,

xi. Updated hazard analysis,

xii. Assignment of action items from the meeting with date of expected resolution,

xiii. Update of progress in closing existing action items.

5. The Contractor shall submit monthly progress reports to the SFMTA no later than five (5) working days following the last calendar day of the reporting month.
6. The status of correspondence submittal and review shall be updated and submitted to the SFMTA as a part of the monthly progress report.
7. The Contractor shall submit special reports and/or shall hold special topical reviews as requested by the SFMTA to address special concerns or problem areas.
8. Documentation of all work, repairs, parts used and purchased, warranties, configuration control of serialized components, and reliability reports shall be submitted to the PMs and VMMs in the form of a report on a monthly basis.

C.2.4 Design Acceptance, Drawings, Documentation and Data Requirements

C.2.4.1 Design Review Procedure

1. Design reviews shall be conducted to evaluate the progress and technical adequacy of the design and compatibility with the performance requirements of the Technical Requirements.
2. The basic method of design review shall be by collaboration of the members of the Team as a continuous process driven by the Schedule.
3. Design review shall include both Preliminary Design Review (PDR) and Final Design Review (FDR).

4. The PDR shall confirm the design concept as well as verify that the activities necessary for production have been collaboratively presented, reviewed, and approved such that they can be released for manufacturing.
5. Acceptance may be subject to conditions provided the conditions can be addressed concurrent with manufacturing.
6. To the extent possible, design reviews of major subsystems and components shall be conducted at the Sub-contractor’s facility.
7. As the design progresses, a continuous series of on-going, concurrent reviews of the design, and the work performed in making the transition from concept to production design, shall be conducted.
8. Collaborative meetings shall be conducted to discuss and evaluate design progress, technical adequacy of the design, system interfaces, and the compliance with the performance requirements of the Contract.
9. During these on-going review meetings, action items shall be identified, with each action item assigned to an individual for disposition by a pre-determined response date.
10. Reviews shall also evaluate compatibility of the functional interfaces between the vehicle subsystem components and between the vehicle and other wayside systems and facilities.
11. Upon reaching agreement between the Contractor and the SFMTA, the Contractor shall prepare and submit the vehicle design drawings and documents for formal review and acceptance by the SFMTA.
12. Technical data shall be handled in accordance with this design review procedure, including:
    a. Management Plans,
    b. Quality Assurance programs,
    c. Production schedules,
    d. Test procedures,
    e. Test schedules,
    f. Test results,
    g. Progress schedules and reports,
    h. Drawing lists,
    i. Samples and other data submitted by the Contractor and requiring review by the SFMTA.
13. Designs and systems that can be proven to have been previously tested and accepted by other authorities with similar specification requirements may be accepted by the SFMTA.
14. FDRs are conducted at the end of each sub-system design.
15. FDRs shall:
    a. Confirm that the design is complete,

b. Confirm that the design is in compliance with the Technical Specification,
c. Confirm that the design is acceptable with regard to the related activities shown on the Schedule,
d. Verify that conditions for approval at PDR have been satisfied and signed for acceptance,
e. Confirms the exact interface relationships between the systems and other related equipment and infrastructure.

16. A FDR shall be conducted when detailed design of a sub-system is complete.
17. The FDR shall determine that detailed design of the system under review will satisfy the design requirements established in these Specifications and shall confirm the exact interface relationships between the systems and other equipment or infrastructure.
18. The FDR shall be considered complete when the Baseline Production Vehicle Design Configuration is fully documented with appropriately revised drawings and documentation as accepted by the SFMTA.
19. Sub-assembly drawings shall also be submitted for information to facilitate the review of assembly and installation drawings.
20. The SFMTA reserves the right to view additional drawings to support the review process of assembly and installation drawings.
21. The Schedule shall provide for time for SFMTA review and disposition of submittals in accordance with the requirements of this section. The following review times (calendar days) are required:
    a. 15 calendar days for submittals unless otherwise noted,
    b. 30 calendar days for structural stress analysis and reports,
    c. 60 calendar days for documents related to:
        i. Manuals,
        ii. Training,
        iii. Parts catalogs.
22. No extension of Contract time will be allowed for revision of Contractor’s drawings or documents that have been either “rejected” or “accepted with comments”.
23. Such drawings and documents shall be resubmitted and will be reviewed and returned to the Contractor within the time intervals stated above.

C.2.4.2 Disposition of Drawings, Documentation, and Data

1. SFMTA review shall provide one of the following dispositions:
    a. Accepted:
        i. “Accepted” is defined as SFMTA concurs with the information in its submitted form.
        ii. Work shall be performed in accordance with the information submitted.
        iii. An acceptance shall not be construed as permitting any departure from the Contract, unless the submittal requests a deviation and

SFMTA issues a Waiver or a Change Order, or relieving the Contractor of any responsibility for the design.

b. Accepted with Comments:

    i. "Accepted with Comments" is defined as SFMTA conditionally agrees with the submitted information in principle, but some details must be changed as indicated by the comments.

c. Rejected:

    i. "Rejected" is defined as SFMTA not accepting the design, requiring the Contractor to revise and resubmit the document, drawing, or data for the SFMTA's review based on the comments provided by the SFMTA. Any physical work performed using "rejected" design data shall be at the Contractors risk.

C.2.4.3 Requirements for Drawings, Documents, and Data

1. The Contractor shall provide all drawings and data required by the Contract Documents, and the SFMTA may request such other drawings and data as needed.
2. Contract documents provided by the Contractor shall be sufficiently detailed to enable the SFMTA to determine with a high degree of confidence (based on applicable industry standards and practices) that the Contractor shall deliver vehicles conforming to the Contract Documents that are suitable for the environment in which they will be used.
3. Drawings submitted by the Contractor shall be in a format approved by the SFMTA and shall include:
    a. A title block,
    b. Drawing number,
    c. Title,
    d. Date,
    e. Revision number,
    f. Contract number,
    g. Reference to next higher assembly,
    h. Signature of the Contractor's responsible engineer.
4. The Contractor shall provide the following documentation for review:
    a. Documents, data, calculations, assembly and installation drawings required to convey:
        i. Concept,
        ii. Design,
        iii. Dimensions,
        iv. Maintenance,
        v. Operation,
        vi. Overall assembly aspects and interfaces.

    b. A narrative description of each major system proposed by the Contractor and Sub-contractors, including arrangement, major components and functional description,
    c. Sub-assembly drawings to facilitate the review of assembly and installation drawings,
    d. A dynamic outline of the vehicle that accounts for the worst-case conditions of wear and failures.
5. All dimensions shall be expressed in the English system. Where other dimensional systems are used, the equivalent English measurements shall be added, leaving the original intact and readable.
6. All terminology used shall be conventional to the U.S. transit and railway industries.
7. Contractor and drawings shall be in a suitable scale in order to accurately convey content.
8. Drawings shall be accompanied by documentation that supports review and acceptance, such as:
    a. Drawings,
    b. Calculations,
    c. Material specifications,
    d. Process specifications,
    e. Flammability and smoke emissions data,
    f. Test data.
9. Detailed parts drawings need not be provided unless requested by the SFMTA to support the review of another drawing.
10. Drawings, documents, and data provided by the Contractor shall be listed in numerical sequence.
11. Drawings shall be prepared in a manner that permits the SFMTA to readily determine and view the interface relationships between major structural elements and their subassemblies, and also between the structural elements and the attached:
    a. Apparatus,
    b. Equipment,
    c. Wiring,
    d. Piping,
    e. Hardware.
12. Drawings shall be made to the third-angle projection system.
13. Structural drawings shall be of sufficient scale and size to clearly delineate the shape and size of all assemblies, members and components.
14. The drawings shall be completely dimensioned.
15. Build-up of materials shall be shown and identified (thickness fully dimensioned).
16. Full and complete information regarding location, type, size and extent of all welds shall be clearly shown on the drawings.

17. All joints and connections shall be detailed, with all dimensions, showing the size of the fasteners, and complete American Welding Society (AWS), or equivalent, weld symbols (including size and process).
18. The list of materials shall include the material's specification including:
    a. Grade,
    b. Temper,
    c. Thickness,
    d. Nominal size.
19. Requirements for vehicle schematics and the Integrated Schematic Package are presented in Section 22.2.1.6.
20. Drawings shall be complete and shall include all interface and complementary drawings, including those for lower order assemblies.
21. If the SFMTA deems a drawing essential and a Sub-contractor claims that the drawing is proprietary, the Sub-contractor shall prove to the mutual satisfaction of the Contractor and the SFMTA that the claim is valid. However, if certain information is necessary for design review or maintenance, the Contractor or Sub-contractor shall supply this information to the SFMTA.
22. The Contractor shall submit design drawings, calculations and system descriptions both to demonstrate that the equipment to be supplied shall fully satisfy all specified requirements and to obtain the SFMTA's agreement.
23. SFMTA and Contractor shall work through the described collaborative review and revision process to arrive at a design of all systems, subsystems and components which is acceptable to the SFMTA.
24. Unless otherwise accepted by the SFMTA, every drawing shall include a complete list of materials and parts lists, including the Contractor's part number, on the field of the drawing or on a separate sheet of the same drawing, describing all parts or subassemblies, and including Sub-contractor-furnished items, which form a part of the assembly, sub-assembly, or piece depicted.
25. All documents, drawings, and data shall provide for a revision block, which shall identify:
    a. The revision letter,
    b. Date of revision,
    c. The initials of the Contractor's responsible engineer authorizing the revision,
    d. A description of the change,
    e. The reason for making the change.

C.2.4.4 Material Samples

1. Material samples of actual decorative and other materials proposed for use on the vehicle shall be provided for SFMTA's review no later than acceptance of the vehicle mock-up or at the time of viewing an existing vehicle.

2. Decorative items such as samples of exterior finish, windows, wall linings, window masks, partitions, interior trim, handholds, upholstery, paint chips, floor covering and any other materials used for decoration shall be supplied in no larger than 8½” by 11”.
3. Decorative items shall be mounted to a backing as necessary and assembled into binders.
4. Each sample shall include Manufacturer name, address, telephone number and all other contact information.

C.2.5 Modification and Configuration Control

C.2.5.1 Configuration Management Plan

1. The Contractor shall submit for review a Configuration Management Plan that describes the method to be used to track and control all component model number; serial numbers; submittals; drawings and revision levels.

C.2.5.2 Drawing List

1. The Contractor shall submit a drawing tree and list of drawings.
2. Based on the guidelines given below, the Contractor shall indicate on this list the drawings intended for submittal and agency approval.
3. The list shall provide space for tracking the submittal status of each drawing.
4. Updates of the drawing list shall be provided with each monthly Progress Report.
5. As part of the drawing tree submittal, the Contractor shall include a description of the primary drawing numbering system including the significance of characters.

C.2.5.3 First Article Inspection

1. First article inspections (FAI) are considered the final step in FDR.
2. The successful completion of an FAI shall be a prerequisite for the completion of the FDR process for those systems and components subject to an FAI.
3. Changes after FDR, and therefore FAI, shall be documented in the form of engineering change proposals and shall be submitted for approval.

C.2.5.4 Design Baseline

1. Production may commence once a PDR acceptance or acceptance with comments is achieved.
2. For the purposes of SFMTA change control, the design baseline for each system shall be established when design acceptance is granted at the FDR.
3. Changes beyond FDR that affect the accepted design or production baseline as presented at the FDR, shall be submitted for acceptance.

C.2.5.5 Documentation

1. The Contractor shall maintain accurate and current configuration documentation, which shall be made available to the agency upon request.

2. The configuration documentation shall have the capability of identifying the following:
    a. The composition of any of the following at any level, in terms of subordinate and next part numbers:
        i. Part,
        ii. Component,
        iii. Sub-assembly,
        iv. Assembly.
    b. Engineering changes and records of superseded configuration requirements,
    c. Configuration of spare parts and any retrofit/replacement requirements.

C.2.6 Component Serialization

C.2.6.1 *Serial Numbers*

3. The Contractor shall assign discrete serial numbers in sequence, including, but not limited to the following equipment and components:
    a. Axles,
    b. Batteries,
    c. Converters,
    d. Couplers,
    e. Door operators and controls,
    f. Gear units,
    g. Journal bearings,
    h. Auxiliary system motors,
    i. Principal units of communications system equipment,
    j. Principal units of traction and braking apparatus,
    k. Temperature control apparatus,
    l. Traction motors,
    m. Truck castings and/or weldments,
    n. Wheels,
    o. Brake control units,
    p. Current collector,
    q. Any other item of equipment customarily assigned serial numbers or that will be rebuilt and/or overhauled.
4. The Contractor shall submit for approval a list of items to be serialized and a description of the serialization method to be used.
5. The Contractor shall provide a completed list of serialized items for each vehicle within the respective Vehicle History Book.

6. Location of serial numbers shall be approved by the SFMTA.

C.2.6.2 Component Identification

1. Format of identification of assemblies, subassemblies, and components shall be in the following format:
   a. Part number ("P/N Abc1234..."),
   b. Serial number ("S/N Abc1234…").
2. The life expectancy of labels shall be the same as that of the part to which it is attached.

C.2.7 Quality Assurance and Audits

C.2.7.1 General

1. The Contractor shall submit a Quality Assurance Manual (QAM) with the Management Plan following award of the Contract. The QAM shall list the Contractor's procedures that describe the methods for planning, implementing, and maintaining quality.
2. The Contractor shall develop a Quality Assurance (QA) program accepted by the SFMTA to oversee the work of the Contract.
3. The goal of the QA program is to explicitly plan for the quality related activities needed to ensure that the product and manufacturing process meet all the requirements of the Contract documents.
4. QA activities and responsibilities include:
   a. Establishing and maintaining a QA program,
   b. Satisfying all requirements identified in the program,
   c. Conducting timely QA audits of the program.
5. The Contractor shall impose its own SFMTA accepted quality assurance program plan requirements on all Subcontractors and Suppliers for this Project.
6. The Contractor shall maintain a surveillance program to monitor all Subcontractors and Suppliers. The requirements of this section shall have precedence in all matters pertaining to program management.
7. The Contractor shall make available for the SFMTA's review and inspection all required procedures, plans, manuals, and any other documentation to be used to ensure conformance.
8. The Contractor's QA program shall, at a minimum, adhere to the guidelines presented in the most current revision of FTA publication FTA-IT-90-5001-02.1 Quality Assurance and Control Guidelines and adhere to ISO 9000 (or QS-9000) series quality standards. Alternate comparable quality assurance and quality control guidelines may be submitted for acceptance by the SFMTA.
9. The Contractor's QA Program shall include the 15 quality elements specified in FTA publication FTA-IT-90-5001-02.1 Quality Assurance and Control Guidelines:
   a. Management Responsibility,
   b. Documented Quality Management System,

c. Design Control,
d. Document Control,
e. Purchasing,
f. Product Identification and Traceability,
g. Process Control,
h. Inspection and Testing,
i. Inspection, Measuring, and Test Equipment,
j. Inspection and Test Status,
k. Nonconformance,
l. Corrective Action,
m. Quality Records,
n. Quality Audits,
o. Training.

10. In addition to the 15 FTA QA/QC elements, the contractor's QA/QC program shall specifically and clearly address the following:
    a. How the quality of the Operator's and the Maintenance Manuals required by Section 22 of this Specification will be assured and demonstrated,
    b. How the quality of the training courses required by Section 22 of this Specification will be assured and demonstrated,
    c. How compliance with the software quality requirements given in Section 18 of this Specification will be assured and demonstrated.
11. Elements may refer to QA/QC activities.
12. QA activities shall include a documented plan for quality activities and verification that those activities were carried out.
13. QC activities shall include the actual implementation of quality activities and the documentation thereof.

The QA program shall remain effective throughout the duration of the Contract.

C.2.7.2 QUALITY ASSURANCE ADDITIONAL REQUIREMENTS

1. The quality assurance program shall include the following elements of the SFMTA quality system and consistent with the Work. The Contractor shall extend to SFMTA its full cooperation and, at no cost to SFMTA, provide facilities at the LRV manufacturing and assembly plants, including final assembly site. These facilities shall enable convenient inspection of materials, work, and equipment. The provisions shall provide for separated, securable office space, desks, locker facilities, file cabinets, free access to a fax machine, free access to a reproduction machine, and free high-speed access to the internet. Copies of all drawings, diagrams, schedules, changes, deviations, and data shall also be furnished. Data shall be sufficient to verify design, construction, assembly, installation, workmanship, clearance, tolerance, and functioning of the LRVs and System Components.

2. SFMTA's in-plant representatives shall be provided with a heated, cooled, and adequately lighted private office for a minimum of three people, with convenient access to restroom facilities. Telephones with an outside line and a fax machine shall be available and dedicated to SFMTA's use within the private office space. The Contractor shall supply three dedicated telephone lines for this use. The Contractor shall provide high speed (100 Mbps or faster, or approved WiFi) access to all on-line project documents and information and the internet. Access to project documents may be by means of a dedicated Internet access line, or through the Contractor’s Local or Wide Area Network, provided adequate security measures are implemented to ensure the confidentiality of SFMTA data on computers connected to such a network.

C.2.7.3 FIRST ARTICLE INSPECTIONS

1. A First Article Inspection (FAI) shall take place at the point of assembly, whether at the Supplier’s or Contractor’s facility, after completion of factory acceptance tests on the first production unit of every component and subsystem to verify proper configuration, materials, operation, and production methods. Major components and systems for which an FAI is required are listed below (SFMTA reserves the right to add to this list):
   a. Car shell,
   b. Vehicle interior,
   c. Completed Cab,
   d. Coupler and draft gear,
   e. Seating,
   f. Door system,
   g. HVAC system,
   h. Lighting components,
   i. Pantograph,
   j. Auxiliary electric components and system,
   k. Propulsion components and system,
   l. Master Controller,
   m. Truck frames, machined,
   n. Completed truck assemblies,
   o. Wheel and Axle assembly,
   p. Friction braking components and system,
   q. Communications system and components, including signs,
   r. Vehicle Monitoring components and system,
   s. Event Recorder,
   t. Train control components and system,
   u. Complete Vehicle prior to pre-shipment.

2. SFMTA shall be notified in writing of the proposed FAI date. The FAI shall be scheduled for a date that is mutually acceptable to both the Contractor and SFMTA. The FAI shall verify that production hardware complies with design configuration and drawings as agreed upon during the FDR. The factory acceptance test procedures and results shall be available for review at the FAI. SFMTA may request the Contractor to repeat the factory acceptance test or parts of it at the FAI. The Contractor shall submit to SFMTA for review and approval the latest approved drawings, test procedures, specifications, quality documentation, and a list of drawings required for adequate evaluation of the equipment under inspection. The list of drawings shall be identified by revision and shall be complete to the line replaceable unit. The FAI report shall be submitted to SFMTA for review and approval after the performance of any FAI. The FAI shall remain open until all FAI items are closed and the Contractor submits a final SFMTA-approved FAI report.

C.2.7.4 SFMTA AUDITS

1. SFMTA may audit the Contractor, or any Subcontractor, at anytime during the term of the Contract. SFMTA may perform quality assurance functions during the life of the Contract. These functions may be performed independently and in addition to the Contractor's activities. These activities will help to ensure that the Contractor is performing the quality assurance functions as defined and agreed to by SFMTA and verify that all services and products delivered to SFMTA conform to the requirements of the Contract Documents. The quality assurance activities of SFMTA will in no way lessen, negate, or replace the quality assurance responsibilities of the Contractor.

APPENDIX D – SFMTA TECHNICAL DOCUMENTS INFORMATION

This section is intended as an example of the standard manual formatting that SFMTA currently receives from contractors for procurement of new vehicles.

D.1 GENERAL

D.1.1 Manuals Format

1. The supplied manuals shall provide complete, concise and clear documentation for all equipment on the vehicle and shall not include superfluous documentation for equipment that was not provided with the vehicle. As well as the printed copies of the manuals, all maintenance operations and illustrated parts manuals shall be provided in digital format on standard CD-ROM media.
2. All such electronic documentation shall be viewable using modern, basic office and multimedia software such as Microsoft Office (minimum compatibility with Office 97 through Office XP) and Windows Media Player. In addition, all materials will be provided in a format that allows their use in the SPEAR Technologies 3i software Image Manager and/or Document Manager modules. SFMTA reserves the rights to electronic reproduction of all such information mentioned herein for its own internal uses, where such electronic reproduction is not already specifically provided for by the Contractor as part of this contract. Within the relevant vehicle warranty period provided for by the Contractor, SFMTA will make no changes to the Contractor-provided documentation where such changes would compromise the intent of the Contractor's original documentation with respect to the safe operation or reliability of the vehicle, unless such change is agreed to in writing by both SFMTA and the Contractor. Where such changes are made, both SFMTA and the Contractor shall maintain coordinated records of the changes, including the SFMTA contract number, manual part number, title, page number(s), date the change was made, who authorized the change, why the change was made, and before-and-after copies of the change. The Contractor shall provide such changes in the same digital format as used for the initial delivery of the manuals. At the expiration of the time periods for Contractor maintenance of the documentation, or upon default of the Contractor in providing such document maintenance, SFMTA shall have the right to reproduce copies of such documentation for internal use only, subject to the warranty concerns expressed herein.
3. All system modifications, retrofits, parts, defect and factory recalls done must include full documentation for recordation into SPEAR Technologies 3i software, plus all parts, service and engineering manuals must be updated regularly.
4. All maintenance documents in electronic form shall be generated for best readability on a 15" video graphics computer monitor at a resolution of 800 by 600 lines per inch, and may exceed the display area in size as required for readability if zooming and/or scrolling is available. The default page setup for all printed maintenance and parts manuals shall be standard U.S. letter size (8.5" by 11") in portrait mode with a gutter

suitable for use in a standard 3-ring binder. Wherever feasible, printed manuals should be organized so that updates or corrections to the manuals can be made with minimal impact to the overall document. Where drawings or other documents are too large to be easily legible in the default page size, such pages may be provided either as 11" tall by 14" (or longer) pages, or as 22" tall by 16" "four-up" pages. In both these cases of oversized pages, the printed page shall be capable of being neatly folded up into the default page size, and shall have suitable reinforcement at the 3-hole edge of the page. Major sections of the maintenance manuals shall be separated by 1/3- or 1/5-cut tabbed and labeled, reinforced index dividers. The printed Operator's Manual shall be a single softbound volume; with at least medium-weight, glossy-stock covers for durability, and may be smaller than the default 8.5" by 11" size, as dictated by the best compromise of readability and portability. An emphasis should be placed on durability and portability. In the interest of readability and clarity, SFMTA may dictate that the Operator's Manual be printed in color.

5. Maintenance, Preventive Maintenance work functions and Illustrated Parts shall include two and three dimensional and exploded view graphics. In addition to providing hard copies and diskettes of these manuals as specified above, the Contractor shall provide required technical services to integrate these items into the SPEAR Technologies 3i maintenance and materials management system. SPEAR Technologies 3i software includes the following applications to support this integration:
    a. Image Manager – Used for providing Illustrated Parts Catalog on-line. Displays images and parts lists, automatically cross-references manufacturer part numbers to SFMTA part numbers and allows users to fill a “shopping cart” with parts requests to perform maintenance activities. Includes Parts Catalog Manager, an easy to use development tool to import and manage graphic and parts list files. Image Manager can also be used for any other graphical documentation, such as wiring schematics, technical illustrations, etc.
    b. Document Manager – Used to link records in SPEAR Technologies 3i software (such as Equipment Asset records, Preventive Maintenance Work Order Templates, Equipment Configurations) to electronic files. System opens the referenced file in its native application using the Windows Registry information for the file extension. Common applications of this module are linking complete technical manuals to coach records, associating digital photos or videos with equipment, and linking troubleshooting guides to template work orders.
    c. Interface Manager – Used to import data into SPEAR Technologies 3i software (such as the Car History Book, Serialized components, Warranty Conditions, etc.) The Interface Manager uses a standard format for data imports.