SECTION 13 - LIGHT RAIL VEHICLE

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13.1.0 GENERAL

This chapter describes the characteristics of the new RTD light rail vehicle (LRV). The new vehicle will be physically and functionally similar to the existing LRV, with changes and improvements as listed below. The designation “SD100/SD160", when used below, refers to the existing vehicles. The designation "LRV", "vehicle", "car", when used below, refers to the new vehicle.

The LRV will be operated on all tracks designated for light rail use of the RTD system and will be operated in-train with the SD100/SD160.

Refer to RTD document "Light Rail Vehicle Specifications, group III, June 30, 1997 Edition" for specification requirements for the SD100/SD160.

The following acronyms are used herein:

AWO Maximum empty vehicle operating weight: 97,000 lb

AW1 Full seated load of 77 persons (passengers plus operator), plus AWO: 108,858 lb

AW2 Standees at 4 persons per m^2 suitable standing space per passenger, 90 persons minimum, plus AW1: 122,718 lb

AW3 Standees at 6 persons per m^2 of suitable standing space per passenger, minimum 136 persons, plus AW1: 129,802 lb

AW4 Standees at 8 person per m^2 suitable standing space per passenger, minimum 180 persons, plus AW1: 136,578 lb

13.1.1 Vehicle Type

The LRV is a single-articulated, six-axle, standard floor low entry car. There are eight passenger doorways, four per side directly across from one another.

Each end of the car has a fully equipped operator's position. Vehicles are capable of multiple unit operation in consists of up to four cars. The anticipated service life of the vehicle is 30 years.

13.1.2 Seating Arrangement

The vehicle will have a minimum of 64 passenger seats, including those designated as flip-up for disabled patrons.

The predominant seating arrangement will be stainless steel pedestals or cantilevered, transverse back-to-back seats. Flip-up seats may be arranged longitudinally.

13.1.3 Elderly and ADA Accessibility

The LRVs, in conjunction with platform configuration, shall comply with the ADA Accessibility Guidelines.

13.1.4 Compatibility

The LRV will be fully compatible with all aspects of the RTD system, including the SD100/SD160, maintenance facilities, clearances, ADA accessibility and operating requirements. It is expected that any LRV that is compatible with the SD100/SD160 must also be compatible with other LRVs that RTD uses in service that may be a different model. The following compatibility requirements will be as follows.

The LRV, when coupled with an SD100/SD160, will be electrically, mechanically and functionally compatible with the SD100/SD160. The LRV will automatically match the performance of the SD100/SD160 when in-train with an SD100SD160, regardless of the location of the SD100/SD160 relative to the LRV.

When not coupled to an SD100/SD160, the LRV shall provide the performance listed below. The LRV anti-climber height and design will match the SD100/SD160.

13.1.5 Winter and Airborne Debris

All vehicle systems must be designed to function under conditions of snow, ice and freezing rainstorms including airborne debris such as leaves, plant seeds, grass cuttings, etc., that may be encountered in the Denver metropolitan area.

13.1.6 Environmental Conditions

Normal operation of the vehicles in the Denver metropolitan area environment shall not in any way impair the performance or useful life. Typical environmental characteristics in the Denver metropolitan area are:

- Ambient temperature - 30° F to + 110° F
- Relative humidity 8% to 100% and condensing conditions
- Maximum Rainfall in 24 hrs. 6.5 in.
- Maximum wind speed 80 mph

- Maximum snowfall in 24 hrs. 18.5 in.
- Freezing rain and ice conditions 1 time/yr.
- Elevation 6000 ft.

13.2.0 GENERAL VEHICLE REQUIREMENTS

13.2.1 Dimensions

13.2.1.1 Carbody Dimensions

TABLE 13A – CARBODY DIMENSIONS

Maximum length of car over coupler faces	24536 mm (80.5 ft.)
Maximum width of car at widest point (excluding mirrors)	2692 mm (8.83 ft.)
Maximum roof-mounted equipment height, exclusive of pantograph, above top of rail (TOR) with new wheels and car at AWO	3810 mm (12.5 ft.)
Nominal coupler vertical centerline height above TOR, car at AWO, with new wheels	605 mm (23.82 ft.)
Maximum floor height above top-of-rail (AWO)	991 mm (39 in.)
Minimum interior ceiling height, finished floor to finished ceiling, on vehicle centerline, except at articulation	2032 mm (6.70 ft.)
Minimum door bottom clearance above top-of-rail (AWO)	260 mm (10.25 in.)
Minimum side door clear opening width with doors fully opened	1237 mm (48.7 in.)
Minimum clear side door height from finished floor	2007 mm (6.58 ft.)
Minimum width of cab door opening	622 mm (24.5 in.)
Minimum height of cab door opening	905 mm (6 ft. 3 in.)
Minimum double seat width	889 mm (35.0 in.)
Minimum seat to wall offset	25.4 mm (1 in.)
Minimum aisle width	660 mm (26.0 in.)
Minimum plus seat thickness, seat pitch	762 mm (20.0 in.)

13.2.1.2 Pantograph Dimensions

TABLE 13B – PANTOGRAPH DIMENSIONS

Pantograph operating height	Maximum: 7000 mm (22.97 ft.)
Dynamic conditions any car weight AWO to AW4, and with new to fully worn wheels minimum	4200 mm (13.78 ft.)
Pantograph lockdown height	3786 mm (12.42 ft.)
Collector head width over horns	1980 mm (6.50 ft.)
Minimum collector head carbon shoe length	1370 mm (4.49 ft.)

The pantograph shall be of a service proven design requiring a minimum of modifications to allow for special operating conditions in Denver.

13.2.1.3 Wheel Dimensions

a. Profile: The car builder shall develop a wheel profile that supports the vehicles operating

b. Diameter

New, nominal: 720 mm (28.35 in)

Fully worn (condemning limit): 660 mm (25.98 in)

c. Nominal back-to-back dimension: 1365 mm (4.48 ft)

13.2.1.4 Truck Dimensions

Variations are permitted, subject to shop hoist and clearance requirements.

a. Nominal truck spacing, centerline-to-centerline:

7720 mm (25.33 ft)

13.2.2 Weights

- The AWO car weight will not exceed 1650 kg per meter of length (1106.4 lbs/ft), measured over the coupler faces.

- The AWO car weight at the center truck is within the range of 25% to 35% of the total car weight.

- The difference in car weight between motor trucks will not exceed 900 kg (1984.2 lbs).

- Wheel load on one side of a truck will not differ by more than 3% from the load on the opposite wheel at AWO.

13.2.3 Curves and Grades

The vehicle shall operate over:

Minimum horizontal curve radius	25 m (82.0 ft)
Minimum vertical curve radius, crest	250 m (820.2 ft)
Minimum vertical curve radius, sag	350 m (1148.3 ft)
Maximum gradient	7%

13.2.4 Clearances

13.2.4.1 General

Maximum normal dynamic roll angle:	2.5 degrees
Maximum dynamic role angle, failed suspension:	4 degrees

13.2.4.2 Undercar Clearances

Vertical undercar clearance is defined from TOR with the maximum suspension deflection and car body roll, minimum vertical curve radius and fully worn wheels.

Minimum vertical clearance under floor mounted equipment shall be 102 mm (4.0 in).

Minimum vertical clearance truck mounted equipment shall be 76 mm (3.0 in).

With the above conditions and with any radius curve, clearances between truck components and the car body shall be no less than 38 mm (1.5 in).

13.2.4.3 Dynamic Envelop and Station Platform Interfaces

The station platform interface shall be as described in Sections 4.2.4.3.b and 5.4.1.

13.2.5 Catenary Voltages

The vehicle, and all vehicle systems, will operate normally at any catenary voltage between 525 Vdc and 925 Vdc, except where indicated otherwise.

No vehicle equipment will generate voltages in excess of 900 Vdc into the catenary system. The SD100/SD160 can operate continuously between 525 Vdc - 900 Vdc.

13.2.6 Performance

All car systems will provide the indicated performance at all line voltage levels between 525 Vdc and 925 Vdc with the nominal voltage rating of 750 Vdc, except the braking systems, which will function at any line voltage down to 0 Vdc.

Acceleration

For vehicle loads from AWO to AW2, and all speeds from 0 to 40 km/h (25 mph), an acceleration of 1.34 m/s (3.0 mphps) will be provided. Time to reach 90 km/h (56 mph) shall be no greater than 35 seconds.

At loads above AW2, the acceleration may be reduced proportionally by the ratio of AW2 to the actual car weight.

13.2.6.1 Service Brake Requirements

Braking will be comprised of a combination of dynamic, regenerative and disc braking. The term "electric braking" will be used to mean dynamic and/or regenerative braking.

Braking efforts on each of the three trucks will be apportioned according to the vehicle weight distribution at each truck.

For vehicle weights up to AW2, motor truck braking will be entirely electric braking. For vehicle weights above AW2, motor truck disc braking will supplement the electric brake. Center truck braking will be via friction disc brakes.

On the motor trucks, friction braking will be automatically blended with electric braking to provide the requested effort.

For all vehicle weights from AWO to AW3, and at all speeds from 0 to 90 km/h (56 mph), an instantaneous service brake deceleration of 1.56 m/s ± 10% (3.5 mphps) will be provided. For vehicle weights above AW2, and speeds greater than 72 km/h (45 mph), electric braking may be tapered to no less than 1.0 m/s (2.2 mphps), with the remaining effort provided by motor truck friction discs.

For vehicle weights above AW3, brake rates shall be proportional to the ratio of AW3 to the actual car weight.

Electric brake fade shall not occur above 8 km/h (5 mph).

In the event of electric brake failure, maximum train speed will be automatically limited to not less than 56 km/h (25 mph). Under this restricted speed condition, the disc brakes shall be capable of providing the above service brake rate, with a ±20% tolerance, without damage to any equipment or brake pads.

13.2.6.3 Emergency Braking Requirements

For brake entry speeds equal to or greater than 50 km/h (31 mph), the minimum emergency brake rate, at all weights up to AW4, shall meet or exceed the values calculated by the following equation:

$$R_{AV} = -0.006v + 2.5$$

Where R_{AV} is the average emergency braking rate in m/s and v is the brake entry speed in km/h.

The maximum emergency braking rate shall not exceed the minimum rates by more than 30%.

For brake entry speeds greater than 25 km/h (15 mph) and less than 50 km/h (31 mph), the average emergency brake rate shall be a minimum of 2.2 m/s (5.0 mphps) and shall not exceed this rate by more than 30%.

For brake entry speeds of less than 25 km/h (15 mph), the instantaneous emergency brake rate after the rate has built up shall be a minimum of 2.2 m/s (5.0 mphps) and the maximum rate shall follow the characteristics of the magnetic track brake.

13.2.6.4 Parking Brake

The parking brake system shall hold an AW4 vehicle on a 7% grade indefinitely.

13.2.6.5 Speed Characteristics

Minimum balancing speed: 90 km/h (56 mph)

(AWO to AW2, level tangent track)

Balancing speed on a 5% uphill grade: 65 km/h (40 mph)

(AWO to AW2, tangent track)

Minimum safe operating speed: 105 km/h (65 mph)

(Fully worn wheels)

The vehicle shall be capable of continuous operation at low speeds of 8 km/h (5 mph) or less. A regulated speed control shall provide a constant speed for car wash and similar activities. This function will be selectable at the master controller, and shall be initially set at 5 km/h (3 mph).

13.2.6.6 Mode Change Dead Times

Mode change dead times will not exceed the following:

Power to Brake	300 ms
Power to Coast	300 ms
Coast to Brake	300 ms
Coast to Power	300 ms
Brake to Power - below 3 mph	300 ms
Brake to Power - above 3 mph	600 ms

13.2.6.7 Jerk Limits

Changes in acceleration or deceleration shall be limited to a fixed rate of change (jerk limit) of 2.0 m/s^3 +10% (4.5 mph/s^2) unless the command signal changes at a lower rate.

Emergency brake applications shall not be jerk limited.

13.2.7 Spin/Slide Correction

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

Efficiency shall be at least 90% in acceleration and in braking for adhesion levels above 5%.

13.2.8 No-Motion Detection

Apparatus shall be provided to detect all vehicle motions down to and including 3 km/h (1.9 mph).

13.2.9 Duty Cycle Rating

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

- A constant AW2 load
- A dwell time of 10.0 seconds at each stop
- Acceleration and braking at maximum rates
- Operation to maximum track speeds
- A 30 second layover at each end of the line

In addition, one train with an AW3 load shall be capable of pushing or towing another train of equal length with an AW3 load from the point of failure to the next station, where passengers would be unloaded, and then continue with both trains at AWO load to the end of the line, at reduced performance, without damage or reduction in equipment life. The point of failure shall be considered to be at the farthest location on the line from either end of the line such that the worst load is imposed on the equipment. The train will be dispatched to the nearest end of the line. The train operating in this condition would be operated as a special equipment movement with no passenger station stops after the first and would slow down only as normally required by other traffic, signals, and civil requirements. Maximum speed may be reduced, by rulebook, to not less than 30 mph.

13.2.10 Electromagnetic Emissions

The vehicle will not produce disruptive electrical interference affecting its own equipment, existing or proposed RTD wayside equipment or other LRVs.

13.2.10.1 Radiated Emission Limits

- From 0.01 MHZ to 30 MHZ, the maximum permissible interference limit shall not exceed 20 dB above the limit of Figure 22 (RE05) of MIL-STD-461 A.
- From 30 MHZ to 88 MHZ, the maximum permissible interference limit shall be 58 dB above one p,V/m/MHZ bandwidth.
- From 88 MHZ to 1000 MHZ, the maximum permissible interference limit shall be 68 dB above one p,V/m/MHZ bandwidth.

13.2.10.2 Conductive Emission Limits

- From 0 Hz to 40 Hz, 10 A maximum.
- From 40 Hz to 120 Hz, 1 A maximum.
- From 120 Hz to 320 Hz, 10 A maximum.
- Above 320 Hz, the emissions limit then follows a smooth curve through 10 A at 320 Hz, 0.08 A at 2 kHz, 0.016 A at 4 kHz and 0.0046 A at 7 kHz.

13.2.10.3 Inductive Emission Limits

The inductive emissions shall be limited to a maximum of 20 millivolts, rms, rail-to-rail, at all frequencies between 20 Hz and 20 kHz.

13.2.11 Noise

Interior noise shall not exceed the following:

- Vehicle stationary: 65 dBA

Windows and doors closed, all auxiliaries operating simultaneously under normal operating conditions

- Vehicle operating: 70 dBA

Car operating on any line at any speed except in tunnels

Exterior noise, measured 15 m (49.21 ft) from the centerline of the track, 1.5 m (4.92 ft) above the ground, shall not exceed the following:

- Vehicle stationary: 65 dBA
- Vehicle operating on tangent track: 75 dBA

13.2.12 Shock and Vibration

Vibrations anywhere on the vehicle floor, walls, ceiling panels and seat frames shall not exceed the following:

- Below 1.4 Hz: Maximum deflection (peak to peak): 2.5 mm
- 1.4hz to 20 Hz: Peak acceleration: 0.01 g
- Above 20 Hz: Peak velocity: C

All vehicle equipment shall withstand the following:

- Car-body-mounted components:
  - Vibrations up to 0.4g peak to peak, at frequencies up to 100 Hz
  - Impact loads of 2g lateral, 3g vertical and 5g longitudinal
- Truck-frame-mounted components:
  - Vibrations up to 4g peak to peak at frequencies up to 100 Hz
  - Impact loads up to 20g each applied individually on any major axis
- Truck-axle-mounted components:
  - Vibrations up to 10g peak to peak at frequencies up to 100 Hz
  - Impact loads up to 50g each applied individually on any major axis

13.2.13 Ride Quality

The rms acceleration values shall not exceed the "4-hour, reduced comfort level (vertical)" and "2.5 hr, reduced comfort level (horizontal)" boundaries derived from Figure 2a (vertical) and Figure 3a (horizontal) of ISO 2631 over the range of 1 Hz to 80 Hz, for all load conditions AWO to AW3.

13.2.14 Flammability and Smoke Emissions

All materials used in the construction of the car shall meet the requirements of NFPA 130 Sections 4.1, 5.2, 5.4 and 5.6.

The floor structural assembly shall meet a 30-minute minimum endurance rating if tested in accordance with ASTM E 119. The ceiling structural assembly shall meet a 15-minute minimum endurance rating if tested in accordance with ASTM E 119.

13.2.15 Reliability

Actual reliability will be based on actual car mileage divided by the average schedule speed on RTD's system, which is approximately 40 km/h (25 mph).

The indicated requirements apply to all unscheduled maintenance activities resulting from equipment failures, whether occurring in revenue service or not.

Individual car systems will meet the following reliability requirements:

MTBF = Mean time between failures

Sub-System	MTBF (hrs)
• Car body & Appointments (including seats, windows, flooring, cab appointments, etc.)	4,000
• Propulsion and Electric Braking (including all drive train components)	4,000
• Friction Braking (including track brakes and sanders)	3,500
• Communications (including destination signs)	7,500
• Passenger Doors and Controls (including ramps)	2,500
• Lighting	20,000
• Electrical (apparatus not included in other systems)	5,000
• HVAC	6,000
• Couplers & Draft Gear	15,000
• Trucks & Suspension	10,000

13.2.16 Maintainability

The vehicle will be designed to minimize Mean Time to Repair (MTTR). The quantitative maintainability goal for the vehicle shall result in an overall MTTR of 1.8 hours. This shall be the weighted average of the MTTR of the key system elements as listed below. Diagnostic time shall be included in MTTR.

Sub-System	MTTR (hours)
• Car body & Appointments (including seats, windows, flooring, cab appointments, etc.)	2.13
• Propulsion and Electric Braking (including all drive train components)	1.77
• Friction Braking (including track brakes and sanders)	1.94
• Communications (including destination signs)	0.82
• Passenger Doors and Controls (including ramps)	0.84

- Lighting 0.50
- Electrical (apparatus not included in other systems) 1.50
- HVAC 2.12
- Couplers & Draft Gear 1.50
- Trucks & Suspension 1.57

13.3.0 CAR STRUCTURE AND INTERIOR

The primary car structural material will be low-alloy, high-tensile (LAHT) steel.

The structure will withstand a 2g load applied longitudinally at the anticlimber without permanent deformation. Collision posts and similar structures above the floor will resist penetration by objects impacting above the anti-climber.

13.3.1 Seats

Seats will be of two varieties: lateral fixed 2 person seats, or flip-up 2 person seats arranged laterally or longitudinally.

All seat frame materials visible to the public will be brushed stainless steel. Non-visible frame materials may be painted mild steel.

Seat cushions will be replaceable insert type.

13.3.2 Wheel Chair Accommodations

Wheel chair accommodations will be provided in accordance with ADA Accessibility Guidelines.

Space for a minimum of two wheelchairs shall be allocated near the operators cab. A stop request tape switch shall be located in this area.

Passenger seats at designated wheelchair areas shall be flip-up type.

13.3.3 Elderly and ADA Accessible Ramps

Each front doorway, nearest the operators cab, will be fitted with a manually operated ramp and bridge plate.

When deployed, the ramps will completely cover the step well, and the bridge plate will rest on the wayside platform.

The status of the ramp will be indicated by limit switch to other vehicle systems.

13.3.4 Windows

The windshield will be one piece laminated clear safety glass meeting FRA Type 1 requirements.

The passenger and door windows will be laminated, tinted, safety glass meeting ANSI Type 1 requirements.

The passenger side windows will be one piece without an openable portion.

13.4.0 COUPLER

The coupler will be an automatic, tight-lock, electrical coupler, which is mechanically and electrically compatible with the existing Scharfenburg/Voith coupler.

The coupler will employ an energy absorption feature that will absorb kinetic energy and prevent car structure damage until the anti-climbers mate.

13.5.0 OPERATOR'S CAB

The general arrangement of the operator's cab shall be similar to the SD100/SD160 cab, with changes and improvements as noted.

- All cab features will be located and dimensioned to accommodate RTD operators in the size range of the 5th to 95th percentile of U.S. males and females.
- The operator's seat will be fully adjustable via electric or manual controls.
- Each sidewall of the cab will include a sliding window. Adjustable shades will be provided for the windshield and both side windows.
- A dual glass, electrically or manually adjustable, mirror will be provided on each side of the cab, viewable through the side windows. Each glass of the mirror will be independently adjustable.

13.6.0 PASSENGER DOORS

The door system shall be outward folding, bi-parting doors or plug doors similar in configuration to the SD100/SD160 doors. Door operators will be electric.

Each door will include a dedicated, microprocessor-based, controller. The controller will respond to external commands, monitor door positions and status, and provide diagnostic and status information to portable test units (PTUs). Basic door operating parameters will be adjusted via the PTU.

Front doors will be operable independently of the other side doors for ADA accessibility.

All door control units will be linked together with a serial data connection such that the status of all doors may be monitored at a single location in the vehicle.

13.7.0 HEATING VENTILATION AND AIR CONDITIONING (HVAC)

Each car half will include a separate, unitized, roof-mounted HVAC unit. Each HVAC unit will function independently of the other, including logic and thermostat controls.

Compressor fluid will be R-22 or R-134a.

The vehicle will include floor heaters to supplement the heat provided by the HVAC units.

13.8.0 LIGHTING

All vehicle lighting will operate from the car's LVPS.

Except for interior passenger lighting, headlights, roof lamps and cab ceiling lights, all lights shall be LED based.

Interior passenger lighting will be via two continuous rows of fluorescent light fixtures along the length of the passenger compartment, except in the articulation. Illumination levels at 840 mm above the floor at any seat will be 375 lux, minimum. Illumination levels on the floor anywhere in the vehicle will be 215 lux, minimum. High-frequency inverter ballasts will power the fluorescent fixtures.

The fluorescent fixture adjacent to each doorway, as well as other specified light fixtures, will be powered directly from the battery to provide emergency lighting during LVPS failure.

13.9.0 ELECTRICAL

13.9.1 Transients

A roof-mounted MOV-type lightning arrester will provide over-voltage protection meeting minimum IEC 1287-1 requirements.

All vehicle equipment will be protected against transient voltages whether generated externally or internally, independent of the lightning arrester.

All equipment capable of generating electrical transients will include suppression devices.

13.9.2 Auxiliary Power Supply

Low Voltage Power System: 28 Vdc

AC Power Supply: 208/120 Vac RMS, 3 phase, 4 wire, 60 Hz.

The vehicle will provide 3-phase 208 Vac power from a static inverter operated from the catenary. Low voltage DC circuits will operate at 28 Vdc, provided by a static converter (LVPS) operated from the catenary. The LVPS and AC inverter may share enclosures, but will have limited common components.

The LVPS will also provide battery charging.

13.9.3 Battery

A 20-cell, nickel cadmium battery will provide back-up low voltage power in the event of LVPS failure. The battery will be sized to carry emergency loads for 1 hour.

13.9.4 Miscellaneous

A pantograph will be provided on each vehicle, mounted such that the head is located over the center truck.

HV circuit protection will be provided by roof-mounted high-speed circuit breaker (HSCB). All other high voltage circuits will be protected by fuses mounted beneath the floor, except as noted below.

Provision will be included to reset the HSCB with a discharged battery. For this purpose, a roof-mounted fuse may provide HV to the inverter/LVPS.

All non-HV circuits will be protected by circuit breakers. All motors on the vehicle will be 3-phase, AC motors.

The quantity of commands and indications for the LRV are expected to exceed the spare pin count on the SD100. As such, many commands and indications not common with the SD100 will be carried via serial and/or multiplexed signals on SD100 spare trainlines.

13.10.0 PROPULSION/ELECTRIC BRAKES

The propulsion equipment will be configured as two independent IGBT-based inverter system, one for each motor truck.

Motortrucks will be configured as bi-motor, parallel drive. Traction motors will be self-ventilated squirrel cage AC motors designed and tested to IEEE Standards 11 and 112, or IEC 349-2. Traction motors will be configured as TEFC or WP Type 1 per NEMA MG1.

The propulsion equipment will provide electric brake effort signals to the friction brake system for blending. The propulsion equipment will provide spin/slide control independent of the friction brake system.

Each propulsion inverter will include a line filter and line contactor for EMI control and isolation from the catenary, respectively. The line contactors will open during emergency

braking. The propulsion equipment will provide regenerative braking whenever the overhead catenary is receptive. In the case when the overhead catenary is not receptive to regenerative braking, the rheostatic braking resistors shall be capable of handling 100% of the load with out damage.

13.11.0 TRUCKS

Trucks will be of proven design, and may be inboard or outboard bearing. Suspension components will be selected to provide a stable and comfortable ride at all vehicle speeds without excessive track or wheel wear.

Primary suspension will be coil spring or rubber elements. Secondary suspension will be coil spring.

Each of the three trucks will provide a load signal to the propulsion and braking systems. Load leveling will not be provided.

Wheels will be resilient types, similar to Bochum 54, with external shunts.

Provision for floor height adjustment to compensate for wheel wear and suspension variation will be provided on each truck.

13.12.0 FRICTION BRAKE

The friction brake equipment will be comprised of hydraulic disc brakes, track brakes and sanders.

Hydraulic disc brakes will be provided on each axle of each truck. The size and quantity of each axles discs will be selected to provide the thermal capacity as defined by the performance requirements. A dedicated hydraulic power unit, each with a dedicated electronic controller, will independently control each truck's disc brakes.

Each electronic control will independently monitor trainlined input commands and local vehicle conditions, as well as the status of its own components, and provide diagnostic and status outputs to a PTU.

Each truck will be provided with two track brakes.

Each motor truck will be provided with sand nozzles for each wheel, with controls arranged to deposit sand only in front of the leading axle of each motor truck.

13.13.0 COMMUNICATIONS

The LRV communication equipment will be comprised of on board train radios, public address (PA) and passenger emergency intercom (PEI). It shall function with a passenger information system, which includes all signs and communication systems. Closed Circuit Television (CCTV) equipment shall also be provided for LRV interior video surveillance.

Radios will be commercial units functionally compatible with the existing RTD radio system, and integrated into the cab console.

The public address system will allow one-way communication between the operator and passengers via the interior and or exterior speakers.

A passenger emergency intercom system will allow two-way communication between individual passengers and the operator. Each vehicle will have 2 intercom stations. A passenger will hail the operator by pressing a button on the station, which sounds a tone in the cab. The operator establishes, and controls, the communication link.

The Automatic Announcement System (AAS) will control all pre-recorded audible announcements. The audio messages will be stored in digital form, and played over the PA system. All functions of the AAS will be trainline.

The PA and AAS will be configured as two independent systems, each system will have a dedicated amplifier.

Destination or route designations will be displayed on the end and side signs. The end and side destination signs will be LED or LCD. The operator will enter the route into a control head via a route ID number. The route ID will determine the sequencing of messages, or other information entered by the train operator.

A Central Control Unit (CCU) will control all portions of the communication system, except for train radio. The train radio will interface with the CCU but in the event of CCU failure the radio will remain functioning.

13.14.0 TWC, ATS AND EVENT RECORDER

This section establishes the requirements for the vehicle Train-to-Wayside Communications (TWC) system, Automatic Train Stop (ATS) system and Event Recorder. The Contractor shall furnish and install all carborne TWC, ATS, and event recorder equipment as described in the following sections. The TWC, ATS and event recorder systems shall be service proven and compatible with RTD's present equipment and operations.

13.14.1 Train to Wayside

The vehicle shall be equipped with a TWC system that is the same or compatible with the Philips Vetag TWC system, represented in the United States by VAPOR Corporation of Chicago, Illinois. The TWC transponders (VAPOR part no. 28836123) mounted at both ends on the center line of the carbody, approximately 10 feet from the end of the coupler. The TWC system uses a wayside interrogator to excite a wayside loop antenna with approximately 0.1 A, at frequencies between 80 kHz. and 120 kHz.

The Vehicle TWC equipment shall be furnished and installed to provide for the accurate transmission of a 19-bit data message from the carborne transponders. The wayside interrogator shall process the following information from the LRVs via the wayside loop antennas:

Active cab:

- Train Number (00-99) 7 bits
- Route Number (00-99) 7 bits
- Stationary Pre-empt/Activation button in cab 1 bit
- Cancel (route) button in cab 1 bit
- Spare 3 bits

Intermediate (inactive) cabs (for multiple-unit consists only):

- Car Number (000-999) 10 bits
- Active Cab (off for intermediate cab) 1 bit
- End-of-train (off for intermediate cab) 1 bit
- Spare 7 bits

Trailing (rear-end, end-of-train, inactive) cab:

- Car Number (000-999) 10 bits
- Active Cab (off for trailing cab) 1 bit
- End-of-train (on for trailing cab) 1 bit
- Spare 7 bits

13.14.2 Automatic Train Stop

Each cab of each LRV shall be equipped with a service proven Automatic Train Stop (ATS) System which shall automatically place the car into an irretrievable braking mode should the Train Operator attempt to pass a red wayside signal. The ATS system consists of both, carborne receiving and control equipment and wayside transmitting equipment. The carborne portion shall consist of two receiving magnets, two car-switching (control) units, a cab control panel in each cab and the necessary brake interface while the wayside portion consists of a transmitting magnet.

The carborne ATS equipment shall function with the existing wayside ATS equipment on the RTD LRT system.

Vehicle ATS equipment shall be installed to be effective only in the normal direction of traffic on a given track and not be effective for reverse movement. In order to prevent a Train Operator from attempting to avoid an ATS trip, by placing a forward moving train into reverse or OFF, the ATS system shall remain active for 20s after the reverser has been moved from forward into neutral or reverse and after the key switch has been placed in OFF.

The ATS equipment shall be interconnected with the car propulsion equipment and braking systems such that only the ATS equipment

associated with the active cab of a car shall be activated in the direction of forward travel. The ATS system shall not be functional when a car is operated in the reverse direction of travel from a given cab.

Each cab shall be equipped with the following ATS control equipment:

- Trip Counter
- Key-By Counter
- "ATS Bypass" indicator lamp
- "ATS Trip" indicator lamp
- "ATS Reset" switch
- "ATS Key-By" switch

13.14.3 Event Recorder

Each LRV shall be provided with a service proven, fully electronic data recorder system, which shall store times, speeds, distances traveled and both analog and digital events as described further below. The event recorder shall be a self-contained unit with data storage and retrieval capabilities. Unless explicitly stated otherwise, the event recorder shall comply with the requirements of IEEE 1482.1, "Standard for Rail Transit Vehicle Event Recorders."

13.15.0 MATERIALS AND WORKMANSHIP

All equipment employed in the construction of these LRVs shall be designed and manufactured to recognized U.S. or international standards for heavy industrial applications. Material and workmanship shall be in accordance with the stated specification or description, unless written approval for substitution is obtained.

13.16.0 TESTING

The complete car and its apparatus shall undergo a comprehensive test program to substantiate required design and performance characteristics. The contractors test plans, procedures and reports are subject to review and approval by RTD. Comprehensive design conformance, production conformance and routine acceptance tests and test procedures are required.

13.17.0 QUALITY ASSURANCE

The Contractor shall plan, establish and maintain a quality assurance program. The elements of the Contractor's quality assurance program shall be required of all entities within the Contractor’s organization and all subcontractors.

13.18.0 TECHNICAL PUBLICATION AND USER EDUCATION

Manuals, integrated schematics, narratives and training are to be provided under the particular LRVs contract. They shall include but not limited to:

- Operating Manuals
- Running Maintenance and Servicing Manuals
- Heavy Repair Maintenance Manuals
- Integrated Schematics and Narratives
- Tools and Test Equipment Maintenance Manuals
- Illustrated Parts Catalogs

Durable "oil proof" pages and binders shall be required per RTD's requirements.

13.19.0 SUPPORT EQUIPMENT

The Contractor shall provide all support equipment necessary for maintaining, troubleshooting, testing, repairing, calibrating and inspecting all carborne equipment. This shall include equipment for the support of shop repair and overhaul activities, for on-board inspection and testing and for maintaining and updating all deliverables.

- Common Tools
- Gauges and Special Tools
- Portable Test Equipment
- Bench Test Equipment
- Repair Data
- Workstations
- Bar Coding Equipment
- Spare Parts