

TECHNICAL SPECIFICATION – SECTION 13

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13 HEATING, VENTILATION, AND AIR CONDITIONING

13.1 General Requirements

13.1.1 System Requirements

The cars shall be provided with an integrated heating, ventilating, cooling, and reheating system (HVAC) to meet the requirements identified in this Section. For the purposes of HVAC control, the car interior shall be divided into two (2) independent zones.

The HVAC unit installed in the A-end shall provide the temperature control, cooling, and overhead heat capacity for Zone 1, and the unit installed in the B-end shall provide control, cooling, and overhead heat for Zone 2.

The Contractor may propose alternative zone arrangements that provide efficient distribution of the conditioned air and optimize the sizing of the ductwork. Alternative zone arrangements shall be service proven for commuter rail application and shall demonstrate compliance with design and performance requirements specified.

All system components shall be service-proven and supported by design and test data adequate to demonstrate compliance with the specified requirements. Details of the system capacity and performance calculation, design, arrangement, installation, and operation of the HVAC system shall be submitted to VRE for review and approval. **CDRL [13-01]**

Table 13-1. DESIGN CRITERIA

Parameter	Value
Ambient Temperature (Summer)	95° F Dry Bulb (DB), 78° F Wet Bulb (WB)
Ambient Temperature (Winter)	-5° F Dry Bulb, 50% Relative Humidity (RH)
Passenger Load	110% of maximum seated capacity (not less than 450 Btu/hr per person with 55% SHR)
Interior Design Conditions	75° F DB and 55% RH (Cooling) 70° F DB (Heating)
Fresh Air	12-25% of total air flow
Total Air Flow	Sufficient to meet the internal temperature, humidity, and car pressurization requirements of this Specification (4800-5200 cfm)
Car Body Heat Transmission	In accordance with the Contractor's car body and insulation design to meet the requirements of this Specification
Lighting Load	Total wattage of interior lights with ballast efficiency of eighty-three (83) percent

Parameter	Value
Solar Load	In accordance with ASHRAE calculation methods.
Miscellaneous Equipment	In accordance with Contractor's design data and shall include, but is not limited to, interior lights, blowers, and equipment

- a. The cooling system shall be able to start and operate without damage at any time of the year when exterior temperature is above 45 ° F. The system design shall allow full cooling operation without the influence of modulation control with the ambient temperature up to maximum anticipated conditions at the condenser and fresh air intakes.
- b. The HVAC system shall be designed and constructed to operate under the shock and vibration conditions specified in Section 3. The HVAC system shall not impose vibrations greater than those specified in Section 3 to the carbody in any mode of operation. Interior and exterior sound levels shall meet the requirements of Section 3.
- c. A comfort control system shall be designed to automatically provide the specified control of car interior temperatures with any ambient temperature from -5 ° F to 95 ° F at the specified wet bulb conditions, with or without variable internal heat loads such as passengers, motors, lights and solar gain, at nominal applied voltages. The cooling system shall also remain in operation, at reduced capacity, if necessary, with ambient temperatures, as defined in Section 3 and Section 17, at the condenser and fresh air intake and design internal and solar loads.

13.1.2 Required Interior Conditions

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

Table 13-2. TEMPERATURE CONDITIONS

Exterior Ambient	Interior
Less than 60 ° F	67 ° F – 70 ° F
60 ° F to 95 ° F	72 ° F – 76 ° F
95 ° F to 110 ° F	Not higher than 20 ° F below the ambient dry bulb
Above 110 ° F	As the system will provide

- a. The interior relative humidity shall not exceed 60% at any time when the HVAC system is operating in the cooling mode. The interior relative humidity shall not exceed 70% at any time when the HVAC system is operating in Layover mode.

- b. When the car interior temperatures are within the ranges specified, the air temperature differential between the car interior and the air leaving the diffuser at the slot outlets shall not be greater than 25 ° F.
- c. The following variations in interior car temperatures are the maximum that shall be allowed throughout the entire car. The criteria apply to all levels of the car:
 - 1) At any given time, except during pull-down and warm-up, among all points in the same horizontal plane from one end of the car to the other: 4° F.
 - 2) At any given time, except during pull-down and warm-up, between any point approximately forty-eight (48) inches above the floor and the corresponding point six (6) inches above the floor in a vertical plane: 4° F.
 - 3) At any given point in the car, and in the entranceways, and at least twelve (12) inches from the ceiling and six (6) inches from the floor and walls over a period of time: 5° F.
 - 4) The average car temperature shall recover within 2° F of the required interior car conditions within two (2) minutes maximum following a thirty (30) second door opening. It shall be demonstrated that this requirement can be met during one (1) hour of continuous door cycling of thirty (30) seconds open and 2.5 minutes closed at design conditions in both air conditioning and heating modes, at the climate room test specified in Section 17.

13.1.3 Ventilation and Pressurization

- a. The evaporator blowers shall operate to ventilate the car whenever the HVAC system is energized. The minimum fresh air supply to the car shall not be less than 1600 cfm.
- b. As a minimum, the following fan design parameters shall be submitted for review and approval by VRE. **CDRL [13-02]**
 - 1) Type, dimensions, model number, and manufacturer of the wheel and housing,
 - 2) Head-flow and power-flow curves for the selected wheel in the selected housing,
 - 3) Manufacturer's maximum allowable wheel speed,
 - 4) Fan wheel balance requirements.
- c. The system design shall ensure a positive interior pressure is obtained in a stationary car with all doors and windows closed and all equipment operating under normal conditions. Positive interior pressure must be maintained at all car speeds regardless of the car's position in a consist or direction of travel. If a contractor's proposal is based on an existing car, then the contractor shall perform a confirming test on the car within 60 days of Notice To Proceed.
- d. Exhaust shall be accomplished statically without the use of exhaust blowers. Static exhaust grilles shall be utilized and properly balanced to assure that the car's minimum positive pressurization and required fresh air quantities are attained. The final balancing settings for the entire air distribution system shall be determined at the climate room test.
- e. A sealed watertight air duct shall connect the interior exhaust grilles with the exhaust openings in the car roof or approved alternative. The exhaust duct shall be designed to preclude the entrance of wind driven snow and rain and shall be sloped to drain any moisture

which may enter the ducts to the outside of the car. The duct shall be arranged such that no water traps can exist.

13.1.4 HVAC Unit Requirements

- a. The preferred arrangement is each vehicle shall have two (2) independent, roof mounted, self-contained modular HVAC units. The units shall be identical and interchangeable among all cars and between ends. The unit shall include:
 - 1) an evaporator,
 - 2) fresh air and supply air fans,
 - 3) compressor,
 - 4) condenser and associated fans,
 - 5) electric heating elements,
 - 6) control unit, thermostat assemblies and filter assemblies.
 - 7) alternative arrangements can be proposed.
- b. The units shall be designed for and initially charged with refrigerant R-407C, or other refrigerant as approved by VRE. The unit shall be constructed of stainless steel except as approved otherwise by VRE.
- c. The units shall be capable of being removed and replaced with the use of an overhead crane with a capacity of 2 ½ tons. Separation of the unit from the car shall be facilitated by quick disconnect mechanical and electrical means and removal of mounting attachments. Taper guide pins shall be provided for ease of precisely locating the unit on the roof. The taper pins shall be mounted to the carbody. The Contractor shall minimize the distance required to lift the unit from the roof. If a lifting jig is required to safely remove the unit, four (4) such jigs and their associated manufacturing drawings shall be provided to VRE. Time required to remove and replace the HVAC unit on the car shall not exceed two (2) hours for two (2) workers. Details shall be confirmed during the design phase.
- d. If applicable, the top of the HVAC unit shall serve as a walkway for maintenance personnel to travel from one end of the car to the other. The designated walkway shall be at least 24-in. wide and shall be clearly marked, etched, and black paint filled stainless steel labels. The walkway area shall have a non-skid surface and shall meet the same load requirements as the roof structure, and as encountered for maintenance, service, and repair activities. Details, if applicable, shall be confirmed during the design phase.
- e. Equipment design and installation shall provide full accessibility for maintenance, troubleshooting, and repair without interference with other systems.
- f. The following components shall be a part of the unit and shall be easily accessible for servicing and replacement either through a hinged grille, which provides access to the return air plenum from the inside of the vehicle, or through an interior access door located in the vehicle ceiling:
 - 1) Air filters,

- 2) All electric and pressure controls,
 - 3) Contactors and circuit breakers,
 - 4) Refrigerant gauge ports,
 - 5) Liquid line sight glass,
 - 6) Return air thermostats,
 - 7) Diagnostic test plug for the PTE,
 - 8) System fault and status LED's, and
 - 9) Crankcase oil sight-glass.
- g. All other components shall be easily accessible for servicing and replacement from within the equipment bay. It is envisioned that air filters and return air thermostats shall be accessible via the return air plenum and the other components through interior access doors in the ceiling area.
- h. All electrical connections to the units, with the exception of the grounding strap, shall be by means of quick disconnects, in accordance with Section 15 for each voltage level.
- i. The units shall be secured to the car structure using a maximum of eight (8) threaded fasteners. The mounting system shall be such that the air-conditioning unit shall be safely retained to the vehicle even in the event of failure of up to 25% of the fasteners. A ground strap shall be provided between the unit frame and the carbody. The unit shall be furnished with lifting provisions, approved by VRE, and shall be removable without disassembling refrigerant piping. **CDRL [13-03]**

13.1.5 CFD Model and Analysis

Within 180 days of NTP, the Contractor shall submit to VRE a Finite Element Model, Computational Fluid Dynamics (CFD) Model and Analysis of the cooling and air distribution system. **CDRL [13-04]**

13.2 Heating

13.2.1 Floor Heat

- a. The total floor heat capacity shall be zoned. The total floor heat capacity in each zone shall be divided into stages of approximately 1/3 and 2/3 of total capacity, allowing for HIGH and LOW power operation.
- b. Floor heating shall be provided using electric strip heaters, powered from the 480 Vac HEP supply, mounted behind stainless steel heater guards along the sidewalls at the floor. The floor heat shall have sufficient capacity to heat the car interior from -5° F to 72° F with the ventilating fans and overhead heat inoperative and without benefit of solar or passenger loads. A five (5) mph windwipe effect shall be reflected in the floor heat capacity determination. In no case shall the capacity be less than twenty (20) kW per car. The required capacity shall be available at 480 Vac. The heaters shall be uniformly distributed.

- c. The electric floor heater elements shall be of the strip-heater type consisting of a nickel-chromium resistance wire embedded in a baked, compressed, refractory material sealed within a rust proof, high heat transfer metal sheath. The maximum allowable watt density shall not exceed 125 watts per linear foot of element when operated at 490 Vac.
- d. The heater strip mounting design shall allow freedom for thermal expansion and contraction of the heater strip, as well as provide full electrical insulation between the heating element sheath and the carbody. The heater elements shall be mounted on approved insulators attached to the carbody not the heater guard. No more than two (2) types of heater elements shall be permitted.
- e. Each heater circuit shall have its own breaker.
- f. The heater elements shall be series wound internally. Electrical connections to the floor heater elements shall be so arranged that electrically live points cannot be reached with a long thin object such as a knife or screwdriver blade inserted through the holes in the heater guard face and section.
- g. The top surface of the heater box shall be sloped in the areas between the seats to prevent accumulation of dirt. No floor heat shall be provided in the car vestibules.
- h. Air shall enter the heater guard through slots at the bottom, pass over the strip heaters, and rise by convection. Holes or slots shall be provided at the top of the heater guard vertical face so that the heated air will exit through the top of the vertical face of the heater guard. The holes or slots shall be small enough to promote convective heat flow while preventing litter accumulation. Where the heaters are located under a window, a portion of the air shall discharge through a slot (1-in x 1/8-in) in the grille under the wainscot lining.
- i. All surfaces of the floor heater enclosures accessible to passengers shall be insulated, if required, to limit the surface temperature to the lowest practical value and in no case higher than 125° F.
- j. Floor heater guards shall be of at least 0.060-in. thick stainless steel. The heater guard front panels shall be constructed so that sections may be removed for replacement of heating strips without dismantling seats. The heater guard front panels shall be fastened at the bottom with no more than five (5) captive stainless screws per panel. The top of the panels shall be held in place with stainless spring clips. Screws shall not be used to fasten the top of the heater guard front panels. The top of heater guard between seats shall be sloped at least 15 degrees to prevent collection of dirt. Stainless steel screens shall be provided on the inside of the heater guard to prevent paper and debris from entering the heater area.

13.2.2 Overhead Heat

13.2.2.1 General

- a. Overhead heaters shall be supplied within the evaporator compartment to provide tempering for fresh air intake and for reheat to maintain humidity control under partial cooling operation of the air-conditioning apparatus.
- b. The heater coils shall be located downstream from the cooling coils and shall have sufficient capacity to heat the total input of fresh air from -5 ° F to 67 ° F at 480 Vac. The heater

elements shall be of the low thermal inertia, open coil, resistance wire type with terminations and insulated supports as approved by VRE. Alternative configurations shall be submitted to VRE for review and approval.

- c. The heaters shall be powered from the nominal 480 Vac supply and shall be staged to provide Low and High power operation.
- d. The heater unit shall be designed to allow easy removal and replacement by means of a maximum of ten (10) captive fasteners. Alternately, individual heater coils shall be capable of being replaced without removing the heater from the HVAC unit.
- e. There shall be no exposed, uninsulated, or unprotected high voltage components, wiring, or terminal connections in the heater area, except the heater element coils.

13.2.2.2 Overhead Heat Protective Devices

The overhead heater elements installed in each HVAC unit shall be protected by circuit breakers. Each stage of overhead heat shall be switched independently by a suitable electro-mechanical or solid-state contactor.

Three (3) stages of overhead heater protection shall be provided. They shall be:

- a. Proof of airflow

An airflow switch, differential pressure switch, or evaporator blower current monitoring device shall be employed to detect and prove airflow through the evaporator section. The proof of airflow method, device, and application shall be approved by VRE. **CDRL [13-05]** The overhead heaters shall not be allowed to be energized if proof of airflow has not been established and loss of airflow, while the heaters are energized, shall cause the heaters to be immediately de-energized.

- b. Overheat Thermostat

An automatically resettable overheat thermostat shall be installed in a location to reliably and accurately sense the temperature in the area of the heater coils. The overheat thermostat shall be wired directly in series with the coil of the overhead heat contactor and shall also provide feedback to the control logic. The setpoint shall be selected such that the overhead heaters may cycle indefinitely on overheat thermostat control with no damage caused to any HVAC system components. The setpoint shall also prevent nuisance trips from any condition that may be expected to arise during normal operation, including operation over the allowed range of input voltage and air filter maximum recommended pressure drop.

- c. Back-up Protection

Back-up protection shall be provided to positively remove power to the overhead heater elements in the event of a control failure or failure of the overheat thermostat. The back-up protection may be a fusible link or may, with the approval of VRE, be a thermostatic sensor wired to a shunt-trip circuit in the overhead heat circuit breaker. The setpoint shall be selected such that no damage shall occur to any HVAC component by temperatures reached before or after the back-up protection device actuates. The setting of the back-up device shall be coordinated such that it will not actuate under any conditions which may be achieved with normally operating controls and functional overheat thermostat.

13.3 Ventilation

13.3.1 General

- a. Ventilation of the car shall be accomplished by centrifugal fans supplied as part of each unit. Ventilation shall be available at all times, in accordance with design criteria of Section 13.1, when the units are operating, including conditions when heating and/or air-conditioning functions have failed.
- b. The ventilation system shall maintain a positive static pressure at all car operating speeds.
- c. Fresh air shall be drawn into each air conditioning unit through a screened, weather-protected section of the condenser air intake grill and shall be filtered and then delivered to an integral mixing plenum. The design shall preclude wind-driven rain or snow from accumulating and leaking into the vehicle interior.
- d. The duct work shall be arranged to drain to the exterior of the car and to ensure no moisture traps or collection points exist.
- e. Recirculated air shall pass through the return air grill and return air filters to the plenum where it shall mix with the filtered fresh air. The mixed air shall then pass through the evaporator coil, overhead heater coils, and evaporator blower. Mixing efficiency of fresh and return air shall ensure that the mixed air entering the coil is at a uniform temperature. Air flow velocity shall be uniform across the entire face of the filters and evaporator coils.
- f. Temperature sensors shall be positioned and protected (if required) to ensure they sense the correct unbiased temperature of the fresh, recirculated, or supply duct air, as appropriate.

13.3.2 Fresh Air Dampers

Electro-pneumatic or motor operated fresh air dampers shall be provided at each fresh air intake or in each fresh air duct to control outside air flow into the car.

The dampers, controlled by the car temperature control system, shall provide two (2) states of operation:

- a. Dampers shall be closed when head end power is off, in layover mode, and during car warm up and pull down according to the temperature schedule.
- b. Dampers shall be open during normal car operation with normal interior temperatures.
- c. In addition, provision shall be included to permit trainline control of the damper position (open or close) and operation of the ventilation blowers, which will allow closing the dampers and turning off the ventilation blowers on the consist when the train enters a tunnel.
 - 1) Control for the damper trainline shall be located both in trailer cars.
 - 2) A damper control toggle switch shall be located in the electric locker of each car to permit the opening or closing of the Fresh Air Dampers. The switch will be labeled, having an indication for the open and close direction.

13.3.3 Motor-Blower Assembly

- a. A motor-blower assembly shall be supplied as an integral part of each unit. It shall blow or draw the air from the mixing plenum through the evaporator and overhead heater assembly and force it into the supply-air ducts from where it shall be discharged into the passenger.
- b. The motor-blower assembly shall be balanced in accordance with IEEE Standard 11. Imbalances shall be less than 0.001 peak-to-peak displacements in any direction at the motor end bells when mounted in the unit. The motor-blower assembly shall be isolated such that motor and fan vibration and noise transmitted to the car structure shall be below the limits specified in Section 3.
- c. The blower motor shall be of a permanently lubricated roller bearing TENV design. It shall operate from the 480 Vac HEP supply.
- d. Motors and blowers shall be easily removable for repair, cleaning, or replacement either individually or as an assembly. Motors and blowers shall also be accessible for routine inspection and maintenance. Blower wheels shall be direct mounted and keyed to the motor shaft. Anti-seize compound shall be applied to prevent the blower wheels from seizing to the shaft. Routine blower assembly inspection shall not be required more often than once every 184 days. The design of the blower wheels and their enclosures shall meet the pressure and volume requirements while producing minimal noise.
- e. The ventilation blower shall also be manually controlled with the fresh air dampers, as described in Section 13.3.2

13.3.4 Unit/Car Body Transition Ducts

The HVAC unit to carbody interface may be such that connection of the unit's discharge to the main air duct is manual when the unit is installed on the car. The design shall preclude the entry of water, dust, or other contaminants into the duct system. Alternate methods of transition may be considered if they do not require tools to connect and disconnect.

Turning vanes, flow straighteners, and sound attenuator shall be included as necessary to ensure that all other provisions of this Specification are met.

13.4 Cooling System**13.4.1 General**

- a. The air-conditioning system shall be capable of cooling and dehumidifying the car with direct-expansion, electromechanical vapor-cycle equipment using R-470C, R-22, or other approved refrigerant.
- b. Every pressure-containing component of the equipment, except piping, shall be listed as having been pressure tested and approved by a nationally recognized testing laboratory. Alternatively, each component shall be designed, constructed, and assembled to have an ultimate strength sufficient to withstand five (5) times the design working pressure. All such components shall be factory tested to at least 1.5 times the design working pressure for which it is rated.

- c. The refrigerant system controls shall include an automatic pump-down cycle. Pump-down shall be initiated by closing the liquid line solenoid valve after an “OFF” signal has been received. System refrigerant shall be transferred to the condenser until the compressor suction pressure drops to an approved value. Pump-down shall not be initiated if the system shut down is initiated by a protective safety device such as excessive pressure, temperature, or current protective devices.
- d. Proof of airflow shall be required to initiate or maintain compressor operation. A pump down shall be immediately initiated if a loss of airflow is detected while the compressor is operating.
- e. Refrigerant piping shall be sized in accordance with recommendations contained in the latest edition of ASHRAE Fundamentals.
- f. Motors supplied in the HVAC system shall be suitable for operation from either an alternator or from a static inverter. The equipment shall tolerate transient phase-to-phase voltage unbalance of up to 20%.

13.4.2 Evaporator Section

- a. The evaporator coil fin assembly shall be housed in a rigid stainless steel frame. The tubes shall be supported at each end and in the center of the coil. The tube support sheets shall be constructed of stainless steel with die-formed support collars for each tube. The evaporator coil shall be of copper fin and copper tube construction with nominal fin thickness of 0.008-in. for flat or wavy fins and with a maximum of ten (10) fins per inch. The tubes shall be expanded to positively retain the fins in position and provide positive thermal contact.
- b. The evaporator coil circuitry shall be split into two (2) separate circuits, using an interlaced circuit arrangement, with each half of the coil being fed by its own liquid line solenoid valve and thermal expansion valve. Solenoid valves and thermal expansion valves shall be identical for each coil circuit.
- c. The design of the evaporator unit shall provide a space of not less than three (3) inches between the evaporator coil and the heater elements to enable the cleaning of the coil by either back blowing or washing. The unit's design shall also prevent any air bypass through the drain pan or around the heat exchanger of the evaporator and heater elements. The coil face area shall be sufficiently large to prevent condensate carryover into the fan plenum or main air duct.
- d. The Contractor may submit an alternate design for a coil with coated aluminum fin construction for consideration by VRE. The alternate proposal must include service history of the proposed coating material in similar severe duty applications and any expected benefits from a cost, reliability, weight saving, efficiency, or other factors offering a benefit to VRE.

13.4.2.1 Condensate Drain System

- a. A condensate drain pan shall be provided beneath the evaporator coil, headers, thermal expansion valves, and coil “U”-bends in order to collect condensation. The drain pan shall be made of stainless steel with stainless steel fittings. The drain pan and fittings shall be

designed so that water cannot spill over into the ceiling area under any operating conditions, including the worst case combination of negative evaporator section pressure, grade, super elevation, acceleration (positive or negative), and car roll. The drain pan shall be mounted in such a way to permit inspection and cleaning of evaporator coils.

- b. Condensate drain lines shall be sloped for positive drainage to the underside of the car and shall not be routed through electrical or electronic cabinets and shall not discharge on car structure, wheels, or brake equipment. An elastomer flapper valve shall be attached to the drain line termination underneath the car. Drain lines shall be arranged to eliminate any potential water traps. The condensate drain lines, coil housing, and pan shall be insulated to prevent condensation formation.
- c. Connection between the HVAC unit’s drain pan and the carbody condensate drain lines shall be made with a heavy gauge flexible tubing, meeting the smoke and flammability requirements of Section 15. Clear access to the connections shall be provided from the interior of the car or equipment bay to allow for unit removal.

13.4.2.2 Air Filters

Fresh and recirculated air or fresh and mixed air shall be filtered by disposable type, two (2) inch thick, pleated media filters of the cardboard frame type in a commercially-available standard size. Face velocity shall not exceed the manufacturer’s recommendation.

Initial clean filter pressure drop shall be a maximum of 0.12-in. of water. Filter performance with a maximum pressure drop of 0.5–in. of water, at a constant velocity of 300 ft/min. Filter efficiency shall be:

Test Standard	Requirement
ASHRAE 52.1	Average dust spot efficiency 25%
ASHRAE 52.1	Arrestance 90%
ASHRAE 52.2	MERV 7

The filters and filter holders shall be sealed at their edges to prevent filter by-pass. Support of the filter elements shall be provided to prevent blowout of the filter elements under clogged filter conditions. Filters shall be readily accessible for replacement from inside the vehicle through the re-circulated air opening.

Air filters shall meet the requirements of UL Standard 900, Class 2, and the requirements of Section 15.

13.4.2.3 Other Evaporator Components

Other components, which shall be included as part of the evaporator portion, are as follows:

- a. A liquid line solenoid valve for each circuit of the two (2) stage evaporator coils. The solenoid valves shall be of a compact design with pilot-operated disc construction. Solenoid valves shall have an operating differential rating of 300 psi minimum.
- b. Thermal expansion valves (TXV's) for each evaporator coil circuit. They shall have external equalizers, and field-replaceable working parts. The TXV diaphragms shall be flat (not corrugated) stainless steel. The TXV's shall be located to provide easy access for maintenance and servicing. The TXV's superheat shall be set at 10° F, +/- 2° F minimum, and the adjustment screw or cap shall be sealed.
- c. An easily removable and serviceable brass-bodied liquid line "Y" strainer provided with 80 or 100 mesh size.
- d. A liquid line sight glass and moisture indicator between the strainer and tee for the each coil circuit. The liquid line sight glass and moisture indicator shall be located to be visible by an individual standing in the vehicle floor. It shall allow observation of the refrigerant flow state. Their location and access shall be subject to approval by VRE.
- e. Two (2) air pressure taps for measuring evaporator coil air pressure drop. The pressure opening diameter in the side wall shall comply with Figure 2 of ASHRAE Standard 51.

13.4.3 Compressor/Condenser Section

The compressor-condenser portion of the self-contained unit shall meet the following requirements:

13.4.3.1 Refrigerant Compressor

- a. The refrigeration compressor shall be a heavy duty, semi-hermetic reciprocating, multi-cylinder transportation type compressor. The compressor shall utilize screened forced-fed lubrication. The oil pump shall function for either direction of rotation. Unloading shall be in two (2) stages and shall provide three (3) capacity steps (approximately 33%, 66%, and 100%). Unloading shall be accomplished with electrically operated suction cut-off unloaders. The compressor crankcase body shall be fitted with removable crankcase heater and crankcase oil sight glass. The crankcase heater shall be powered by the low voltage DC power supply. The power wires for the heater may be contained in the same conduit as the AC wires that supply the HVAC units. The compressor shall be provided with oil drain valve and an oil charging port. The compressor shall use separate compression and oil rings unless approved by VRE.
- b. The Contractor may propose an alternative refrigerant compressor unit that provides enhanced interior comfort and increased system reliability. The alternative unit shall provide at least five (5) capacity steps (approximately 35%, 50%, 70%, 85%, and 100%). The alternative refrigerant compressor unit shall be service proven for commuter rail application and shall demonstrate compliance with the design and performance requirements specified. Details of the alternative refrigerant compressor unit and its integration into the HVAC system shall be submitted to VRE for review and approval.
- c. The compressor shall be resiliently mounted within the HVAC unit. A flexible copper strap shall be provided to electrically ground the compressor to the unit frame.

- d. The HVAC compressor shall be powered from the 480 Vac HEP supply.

13.4.3.2 Condenser Coil Assembly

- a. The condenser coil(s) shall be housed in a stainless steel frame with suitable fan shrouding and protective screening. The coil(s) shall be of a copper tube and copper fin construction with minimal fin thickness of 0.008-in. for flat fins. Maximum number of fins shall be eight (8) per inch. The tubes shall be expanded to positively retain the fins in position and provide positive thermal contact.
- b. The tube support sheets shall be constructed of stainless steel with die formed support collars for each tube. A center tube support sheet shall be provided if the total tube length is greater than thirty-six (36) inches.
- c. The coil shall utilize copper tubes of sufficient wall thickness to withstand system pressure. The coil shall be designed with adequate capacity to provide a maximum condensing temperature no greater than 30° F above the condenser cooling air temperature under conditions of full-rated load. The coils shall also be designed to ensure that the air-conditioning system can operate under extreme ambient conditions without the risk of creating abnormal system pressures.
- d. The condenser coil shall be proof tested by the manufacturer at 1.5 times the maximum pressure or 600 psig, whichever is greater. As an alternative, the first coil may be burst tested to demonstrate a positive margin of safety and all other coils proof tested to 425 psig.

13.4.3.3 Condenser Fan and Motor

- a. The condenser fan(s) shall be driven directly by three (3) phase, 480 Vac motor(s), powered from the 480 Vac HEP supply. The motors shall be totally enclosed and rated for wash down applications with permanently lubricated rolling element bearings and have sufficient capacity to drive the condenser fan under all load conditions. A flexible copper strap shall be provided to electrically bond the condenser fan motor frame to the HVAC unit structure. Motor installation, with its shaft vertically up, shall require the application of a slinger on the motor shaft to prevent moisture penetration to the inside of the motor.
- b. The fan(s) shall be a multi-blade axial fan(s) and the blades shall have airfoil profiles, or approved equal, to ensure optimum fan efficiency and minimum noise generation. Connection of the fan hub to the motor shaft shall be by a tapered bushing type hub with a key. To facilitate removal of the condenser fan, the condenser fan motor shaft shall be of a corrosion-resistant material, or it shall be treated to prevent corrosion and seizing of the fan hub on the shaft.

13.4.3.4 Condenser Airflow

- a. Condenser cooling air shall enter the unit through the condenser air intake grill on the side of the car, pass through a section of stainless steel duct, and enter the coil.
- b. Hot air, discharging from the condenser coils, shall pass through the condenser fan(s), a stainless steel duct, and shall be discharged through the roof mounted discharge grill. The

grill shall be designed so that condenser airflow is not affected by the direction or speed of car motion.

- c. Connections between the intake and discharge ducts and the intake or discharge grill and between the ducts and HVAC unit shall be through neoprene coated fiberglass fabric isolators. The use of tools shall not be required to disconnect the condenser air ductwork from the HVAC unit.
- d. The entire condenser system air side shall be sealed such that water or snow entering the condenser section cannot enter the equipment bay under any operating or non-operating condition.
- e. The condenser section shall be provided with drains, separate from the condensate drains, discharging under the car. The drain pipes shall be fitted with elastomer flapper valves.

13.4.3.5 Other Condensing Section Components

- a. A serviceable, "catch-all" type filter-drier assembly as manufactured by Sporlan, or approved equal, shall be provided in the liquid line. The filter-dryer capacity of water, refrigerant flow, filtering area, and acid removal shall be specified based on ARI Standard 710. The filter drier shall have rust proof shutoff valves on each side to isolate it for servicing. An access fitting shall be provided on one (1) valve to allow recovery and evacuation of the filter-drier section.
- b. A discharge-line check valve.
- c. A fusible plug as recommended by UL 1995.
- d. Service valves in the compressor suction and discharge line connections to provide for isolation and replacement of the compressor. The service valves shall also be provided with service access ports, at least one (1) of which must allow access to the compressor when the associated valve is front-seated (closed).
- e. All service valve caps shall have a metal-to-metal seal. Service valve and sight glass caps shall be safety chained to the unit to retain them with the valve or sight glass when removed.

13.4.4 Refrigeration Control Compartment

The refrigeration control compartment shall be accessible from the return air plenum with the unit installed on the car. The refrigeration control compartment shall contain the following devices:

13.4.4.1 Low-Pressure Cutoff Switch

- a. A low pressure cutoff switch shall be provided to monitor compressor suction pressure to protect the compressor and other system components from potentially damaging low pressure operation.
- b. The switch shall directly deactivate the control circuit to the compressor motor when the pressure drops below the safe limit.

- c. The switch shall automatically reset and energize the compressor motor when the pressure rises. Suitable hysteresis shall be provided in the system to prevent short term system cycling at the cut-out pressure.

13.4.4.2 High-Pressure Cutoff Switch

- a. A high pressure cutoff switch shall be provided to monitor the compressor discharge to protect the system from excessively high system pressures.
- b. The switch shall immediately de-energize the compressor when the discharge pressure reaches approximately 400 psig.
- c. The switch shall be wired directly into the compressor contractor control circuit. The switch shall automatically reset and energize the compressor motor when the pressure drops to approximately 340 psig.
- d. The circuit shall be arranged such that condenser fan operation is not interrupted by the high pressure cutoff control. A time delay of fifteen (15) seconds (minimum) shall expire prior to the restart of the compressor following achievement of the reset pressure.
- e. The high pressure cutoff switch shall be provided with an external pulsation snubber.

13.4.4.3 Modulation-Pressure Switch

- a. A modulation pressure switch shall be provided to monitor discharge line pressure and maintain system operation by reducing the air conditioning system capacity when conditions cause discharge pressures to approach the high-pressure cutoff point.
- b. The control shall force the system into modulated ($\frac{1}{2}$) cooling when the discharge pressure exceeds an approved value. The control shall automatically reset when the pressure drops to restore full cooling operation.
- c. Alternately, a transducer monitoring the discharge line pressure may be used for this function.

13.4.4.4 Unloading Control Transducer

- a. An unloading control transducer shall be provided to monitor the compressor suction line and control the compressor capacity.
- b. The compressor capacity shall be reduced to match compressor capacity to the existing load and to prevent the saturated suction temperature from falling to an unacceptably low level.
- c. Other suction pressure based control functions, including compressor shut down after pump down, may also be controlled from this transducer. Alternately, a suction line pressure switch or switches may be used for this function.
- d. Alternate methods of capacity control may be proposed for consideration and approval by VRE.

13.4.4.5 Pressure Switch and Transducer Construction and Mounting

- a. All pressure switches shall be snap-acting with stainless steel wetted parts. The fluid side of the switch shall be hermetically sealed.
- b. Transducers shall have stainless steel wetted parts and shall be hermetically sealed.
- c. Pressure switches or transducers shall be connected to the system using flare type connections. The system side of the connection shall be equipped with a check valve to allow switch replacement without the need to recover the entire refrigerant charge from the system.

13.4.4.6 Gauge and Service Ports

High and low side gauge and service ports shall be provided. Each port shall be fitted with a self-sealing, Schraeder type valve, with chain-retained, metal-to-metal seal caps. Each line shall be equipped with a diaphragm type manual isolation valve. The manual valves and gauge connections shall be color coded red for high side and blue for low side.

13.4.5 Piping Design and Installation

- a. The refrigerant piping design, installation, and piping materials within the unit shall meet the requirements of Section 15. The length of pipe between joints shall not be less than the maximum length, which can be installed without damaging the pipe or equipment. The piping installation shall be such, however, that it shall be possible to replace any length of pipe using ordinary methods and without having to remove any other equipment.
- b. All pipe insulation shall meet the flammability and smoke emission requirements of Section 15
- c. Vibration eliminators shall be provided where any refrigerant line attaches to a resiliently mounted assembly, including the compressor suction and discharge lines. The vibration eliminators shall be provided with neoprene covering over the flexible bronze wire braid to provide resistance to abrasion and prevent condensation from freezing behind the ferrules.
- d. Suction lines shall be designed and constructed without horizontal traps and sized for a maximum pressure drop of three (3) psi.
- e. The liquid line shall be sized to prevent flashing due to pressure drop.
- f. All refrigerant lines shall be adequately supported to prevent vibration, chafing, fatigue, and stress of joints. All capillary tubes shall be arranged to prevent any metal-to-metal rubbing caused by vibration.

13.4.6 Electrical Compartment

The electrical compartment shall be an integral part of the unit. It shall be accessible for system maintenance and servicing through the return air grill or ceiling access panel.

The electrical control compartment shall contain the following components:

- a. Relays, contactors, solid state power controllers, and individual component isolation circuit breakers.

- b. Electrical controls.
- c. Diagnostic test plug for attachment of the PTE.
- d. Power and control wire terminals.
- e. Main and control power disconnect switches.
- f. Static temperature control unit.
- g. Fault and status indication panel.

Contactors for floor heat control may be installed in the HVAC unit electrical compartment or may be installed in a separate enclosure.

13.4.7 Insulation

Refrigerant suction lines shall be wrapped with a fire retardant, closed-cell foam insulation. All insulation and adhesives shall meet flammability, toxicity, and smoke emission requirements of Section 15. All piping insulation corners shall be mitered and sealed with a sealant recommended by the manufacturer of the insulation.

The evaporator section shall be insulated to prevent condensation formation on the outside of the HVAC unit.

13.4.8 Evacuation-Dehydration

The HVAC equipment manufacturer shall evacuate and dehydrate the system to fifty (50) microns pressure or less. This vacuum must be maintained for a minimum of two (2) hours with the vacuum pump running. After two (2) hours, the vacuum pump shall be isolated from the system. The system pressure shall not rise above 300 microns in a two (2) hour period after vacuum pump isolation.

13.4.9 Refrigerant Charge Determination

The refrigerant charge weight shall be determined during the equipment qualification test. The refrigerant charge established at this test shall be included on the unit nameplate.

13.5 Temperature Control

13.5.1 General

- a. The control of the HVAC system shall be designed to automatically maintain the car interior temperature, at the specified conditions, with or without variable internal heat loads such as passengers, motors, lights, and solar gain.
- b. All control components and circuits shall operate from the nominal 120 Vac supply.
- c. Layover settings for both layover heating set-point and layover cooling set-point shall be adjustable.
- d. The sensitivity and accuracy of the controls shall permit the requirements of Section 13.1 to be met. Temperature control of each zone shall be independent.

- e. The final selection of temperature control arrangement shall be approved by VRE and shall be verified at the system qualification and vehicle climate room tests. **[CDRL 13-06]**
- f. Local control of the heating and air conditioning shall be fully automatic when the HVAC control system is energized and HEP is available.
 - 1) Cut-out of the HVAC system(s) on individual cars may be accomplished by isolating 74 Vdc control power to the control(s) by switching off the HVAC Control Breaker for the desired unit.
 - 2) With the HVAC Control Breaker in the “ON” position, the HVAC system shall operate automatically in response to “HVAC Start” or “HVAC Stop” commands or in response to the layover thermostat.
- g. The HVAC system shall sense air dry bulb temperatures, as required, with thermistor sensors. Thermistors shall be encapsulated in a protective stainless steel tube. The layover thermostat shall be a passenger rail service proven bimetallic or liquid-filled type with set points as required herein.
- h. Temperature sensors shall be mounted to insure that they are not unduly influenced by local sources of heat, such as motors or resistors; that they are easily accessible for maintenance and replacement; that they are protected from damage during routine maintenance and servicing, such as replacing filters; and that they are not unduly influenced by fresh air. Sensor accuracy shall be required to comply with the requirements of this Specification.
- i. The static temperature controls shall control the heating, ventilating, and air-conditioning contactors directly through power switching transistors provided as part of the unit without the use of pilot relays.
- j. The static temperature control electronics shall be selected in strict conformance with the specified requirements and shall be packaged in a single rugged, totally enclosed sheet metal enclosure. Required heat dissipation shall be accomplished by external cooling fins arranged to avoid the collection of dirt. The unit enclosure shall be arranged for quick removal and replacement with no more than four (4) captive fasteners. Electrical connections, including portable test unit connections, shall be by means of 1/4 turn ITT Cannon-Veam or equivalent environmentally sealed connectors.
- k. HVAC System status and failure event information shall be reliably and accurately recorded. The reporting methodology and format of the display of this information shall be submitted to VRE for review and approval. **CDRL [13-07]**

13.5.2 Control Operation

Operation of the HVAC System shall be fully automatic at all times that low voltage DC and 480/120 Vac power is available. The system shall function to maintain the required interior conditions listed in Section 13.1 for each zone.

13.5.2.1 Cooling Control

- a. Each control system shall control the operation and unloading of the refrigerant compressor and the staging of the overhead heat (reheat) in response to the sensed return air temperature

(including the rate of temperature change), refrigerant pressures, ambient temperature, and other factors, as necessary, to maintain the interior conditions listed in Section 13.1. The control logic shall preclude rapid cycling of any device.

- b. When the cooling demand has been satisfied, the system shall perform a pump-down of the refrigerant circuit. The pump-down cycle shall end when the suction pressure reaches an approved value. **CDRL [13-08]**
- c. Compressors shall start in their maximum unloaded condition. Compressor starts shall be coordinated over the train network to ensure that only one (1) compressor per consist attempts to start at any given time.

13.5.2.2 Heating Control

The overhead heat shall be controlled such that the power offsets the fresh air ventilation heating load, except during pull-up, when the overhead heat shall operate at full power. The floor heaters shall be cycled, as required, to offset all other losses and maintain the interior conditions within the requirements of Section 13.1 for each zone. The size of each stage shall be arranged and controlled to minimize the cycling of the heat control contractors.

13.5.2.3 Overhead Heat

A duct temperature sensor shall be provided for use in controlling the overhead heat. Each control system shall cycle the overhead heater between HIGH and LOW power, as required, to maintain the delivered air temperature, as measured by the duct sensor at, or no more than 8° F above, the return air temperature.

In order to reduce cold car pull-up time, the overhead heat shall operate at HIGH power when the return air sensor reading is 10° F or more below the required interior temperature.

13.5.2.4 Floor Heat

Each control system shall cycle the floor heaters between HIGH and LOW power, as required, to maintain the required interior temperature. Control schemes that utilize the rate of change of the interior temperature as well as the actual value are encouraged.

13.5.2.5 Layover Control

In Layover Mode, layover thermostats for each zone shall be installed in a protected area of the vehicle. The layover thermostats shall

- a. Operate the floor heaters in each zone to maintain a minimum average interior temperature of 45° +/- 5° F at any ambient temperature below 40° F.
- b. Operate the Air Conditioning Unit to maintain a maximum average interior temperature of 80° +/- 5° F at any ambient temperature above 85° F.

Additionally, in Layover Mode, the system shall operate the Air Conditioning Units to maintain a maximum humidity of 70%. The humidity set-point shall be adjustable.

13.5.3 Control Unit

The HVAC system shall utilize a Control Unit approved by VRE. The unit shall be powered by the 120Vac system. The unit shall be designed and constructed to properly interface and control the HVAC system.

13.6 Ducting

- a. Air distribution ducts for the upper and lower levels shall run the length of the level in the corner at the intersection between the side wall and ceiling.
- b. The material selection for the duct work shall be approved by VRE **CDRL [13-09]**. Considerations shall include, but are not limited to, thermal insulation performance, as required, to prevent condensation on the exterior of the duct under all conditions, acoustic insulation such that the interior noise requirements of Section 3 are met, weight, appearance, and ability to repair. The air velocity within the duct work is not specifically limited but shall be such that, in combination with the acoustic insulation, shape, and diffuser design, the interior noise and vibration requirements of Section 3 are met.

13.7 Interior Grills

13.7.1 Passenger Compartment Diffusers

- a. A continuous linear slot diffuser shall run the length of the air ducts in the upper and lower levels. The diffuser shall be installed in the vertical side of each duct nearest the car center line. Diffusers shall be anodized aluminum, in a color in accordance with the interior design requirements.
- b. Diffusers shall be easily adjustable on the climate room test car only. All other cars shall have non-adjustable diffusers with the same settings, as approved, in the climate room test.
- c. The diffuser design shall preclude a cylinder two (2) inches long and ¼-in. in diameter from entering the duct.
- d. The mixing efficiency of the diffusers shall be such that an equal mass of room air is entrained and mixed with the discharge air at a distance of six (6)-in. (152 mm) from the face of the diffusers. The maximum velocity of discharged air shall not be greater than 150 fpm at six (6)-in. from the diffusers. Maximum air velocity throughout the car interior shall not exceed 100 fpm at 60-in. above the floor and 50 fpm at 48-in. above the floor.
- e. Interior diffusers must be designed so as to comply with all interior noise requirements in Section 3.4.

13.7.2 Return Air Grill

- a. A return air grill or grills shall be provided in approved locations for each HVAC unit. The return air grill shall be of sturdy and rattle-free construction and shall have a core and satin-finished frame of anodized aluminum. The recirculated air grill shall be designed to pass the required quantity of air with sound levels such that the requirements of Section 3 are met anywhere one (1) foot from the grill.

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

13.8 Exterior Intakes

13.8.1 Fresh Air Intake

A portion of the condenser air intake grill, described in Section 13.4.3.4, shall be reserved for a fresh air intake. Fresh air shall not be drawn from the ductwork supplying the condenser coil(s). Suitable acoustic insulation shall be provided to prevent condenser fan noise from entering the car interior through the fresh air system.

13.8.2 Water Eliminators

Water eliminating baffles or louvers shall be provided to prevent water, which enters the fresh air intakes, from being drawn into the unit. Eliminators shall be fabricated from stainless steel. Cleaning and servicing of the water eliminators shall not be required more often than once a year without any significant reduction in the system performance. Fresh air filters shall not be considered part of the water elimination design.

13.9 Protective Heaters

13.9.1 Protective Heaters

Other car systems and components, including, but not necessarily limited to: door threshold heaters, brake valves, reservoir drain valves, and coupler heads may require protective heaters. The Contractor may utilize temperature information from the HVAC system sensors for these devices, or they may contain integral thermostats. The Contractor shall provide details of the protective heater control for approval by VRE. **CDRL [13-10]**

13.9.2 Door Pocket Heaters

Anti freeze protection, activated at an outside temperature of 46° F, shall be provided for the door thresholds, and a convection heater for the door pocket area shall be provided. All heaters shall be strip type heaters, controlled by an external thermostat and relay. No interior furnishings, such as seats, floor heaters, windscreens, etc., shall require removal for replacement of heaters. It shall be demonstrated that qualified personnel can remove and replace the heaters in no more than twenty (20) minutes. Details of the design, installation, and removal tasks shall be submitted to VRE.

13.10 Referenced Standards

- ARI Standard 710, Liquid-Line Driers
- ASHRAE Standard 51, Laboratory Methods of Testing Fans for Aerodynamic Performance Rating

- ASHRAE Standard 52.1, Gravimetric and Dust-Spot Procedures for Testing Air-Cleaning Devices Used in General Ventilation for Removing Particulate Matter
- ASHRAE Standard 52.2, Method of Testing General Ventilation Air-Cleaning Devices for Removal Efficiency by Particle Size
- IEEE Std 11, Rotating Electric Machinery for Rail and Road Vehicles
- UL Standard 900, Test Performance of Air Filter Units
- UL Standard 1995, Heating and Cooling Equipment

13.11 Contract Deliverable Requirements List

CDRL #	Title
13-01	HVAC System-Design and Installation
13-02	Blower Design
13-03	HVAC Unit Lifting Provision
13-04	CFD Model and Analysis
13-05	Proof of Air Flow
13-06	Temperature Control Arrangement
13-07	Reporting Method for HVAC System
13-08	Suction Pressure
13-09	Main Air Ducts
13-10	Protective Heater Control- Details