February 18, 2015

To Whom It May Concern:

This letter constitutes Addendum No. 2 to SEPTA RFP No. 14-237-JFK for High-Speed Electric Locomotives.

Addendum No. 2 consists of the following:

1. Answers to Questions 33 through 40, inclusive, plus the red-lined version of changes to the specific sections of the Specification. Refer also to Addendum 2 Change Tracker.

Note that Specifications sections included within this Addendum are erroneously footnoted as “Section xx Proposal Copy - Addendum No. 1” instead of “Section xx Proposal Copy - Addendum No. 2”. This will be corrected in a future Addendum.

Addendum No. 2 must be acknowledged by updating and signing the Acknowledgement of Addenda Form and including with your Proposal.

Any inquiries regarding this Addendum must be directed to John Kerrigan of the Procurement and SCM Department at jkerrigan@septa.org or 215.580.8360.

Sincerely

John Kerrigan

John Kerrigan
Contract Administration
Procurement and SCM Department
ACKNOWLEDGEMENT OF ADDENDA FORM

RFP 14-237-JFK – High-Speed Electric Locomotives

Acknowledgement of Addenda

The following form shall be completed for the acknowledgement of all addenda by inserting the dates next to the appropriate addenda number and including in the Technical Proposal submittal. Failure to properly acknowledge the addenda, as set forth below, may cause your proposal to be considered non-responsive to the solicitation.

The undersigned acknowledges receipt of the following addenda to this RFP No. 14-237-JFK and certifies that all changes have been taken into account in the total price of the proposal.

ADDENDUM NO. 1    DATED: ____________
ADDENDUM NO. 2    DATED: ____________
ADDENDUM NO. 3    DATED: ____________
ADDENDUM NO. 4    DATED: ____________
ADDENDUM NO. 5    DATED: ____________
ADDENDUM NO. 6    DATED: ____________

Proposer Name: ________________________________________________________________
Street Address  : ________________________________________________________________
City, State Zip   : ________________________________________________________________
Signature of Authorized Signer: ____________________________________________________
Print/Type Name : ________________________________________________________________
Phone Number     : ________________________
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<thead>
<tr>
<th>Ref No.</th>
<th>Volume</th>
<th>Section</th>
<th>Page</th>
<th>Resp.</th>
<th>Request for Clarification Details</th>
<th>SEPTA Response</th>
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</thead>
<tbody>
<tr>
<td>33</td>
<td>Section 2</td>
<td>2.2.13.1</td>
<td>13</td>
<td></td>
<td>The spec says: Receptacles of each type shall be installed on all four corners of the locomotive to allow locomotives to turned randomly end-for-end in a consist. In order to use SEPTA standard length jumper cables between locomotives as well as to adjacent cars, the location of the receptacles in all three axes must be coordinated with those of existing SEPTA equipment. Request for clarification: For receptacles, please see request for clarification related to chapter 2.2.12.3 For the use of SEPTA standard jumper cables, please provide drawings and minimum.</td>
<td>The Contractor shall supply trainline cables for connection of the locomotive to SEPTA's existing push pull fleet. The trainline cables do not need to be identical to SEPTA's existing cables. The specification has been modified accordingly.</td>
</tr>
<tr>
<td>34</td>
<td>Section 2</td>
<td>2.2.13.3</td>
<td>15 of section 2</td>
<td></td>
<td>How is the information of a “car hot journal” transmitted to the locomotive for indication? Pin 21 of the communication trainline is not used as “Hot Journal indication” but as “Doors Open – Left Side Low Level” information (see section 2.2.13.2)</td>
<td>Car hot journal is not used on SEPTA equipment. The specification has been modified accordingly.</td>
</tr>
<tr>
<td>36</td>
<td>Section 2</td>
<td>2.2.13.6</td>
<td>16 of section 2</td>
<td></td>
<td>Black MU trainline currently has no signals to control dynamic brake independently of pneumatic brake in train via an analogue voltage signal. Are there plans to change the MU trainline pin assignment to provide wires for this functionality</td>
<td>Actuation of the dynamic brake is not performed on a trainline basis. It is not a requirement to provide electric propagation of dynamic brake; cab cars do not have any controlling element to provide this signal. It is not anticipated that this function will be added. Brake blending while configured as trailing is to be controlled via brake pipe reductions when appropriate. No specification change is necessary.</td>
</tr>
<tr>
<td>37</td>
<td>Section 11</td>
<td>11.6</td>
<td>15 of section 11</td>
<td></td>
<td>The requirement of section 11.6 “Positive indication of the parking brake status shall be provided to the controlling cab via trainline 14 of the MU receptacle.” is in contradiction to section 2.2.13.6 where Pin 14 is used for “Pantograph Down” and no other signal is defined for Parking brake indication resp. control Suggestion is to use PIN 11 for this indication.</td>
<td>The requirement to provide positive indication of the parking brake status via trainline 14 of the MU receptacle has been deleted from the specification. The parking brake status shall be included in the overall brake applied status via pin 20 of the communication trainline.</td>
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<tr>
<td>Ref No.</td>
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<tr>
<td>38</td>
<td>Section 11</td>
<td>11.1.8</td>
<td>3 of section 11</td>
<td></td>
<td>“Provide a spring-applied, air-released parking brake control signal to unit car in the train consist which shall be controlled from the active locomotive cab.” Please specify relevant trainline pins to communicate parking brake apply and release commands to trailing locomotives or coaches</td>
<td>The requirement to provide consist level control of the parking brake has been removed from the specification.</td>
</tr>
<tr>
<td>39</td>
<td>Section 2</td>
<td>2.2.13.6</td>
<td>17 of section 2</td>
<td></td>
<td>Please confirm functionality of pin 22 “Emergency Brake”: Signal will be read by leading vehicle, whenever signal is active an emergency brake will be triggered by the lead locomotive. Signal is generated in the coaches.</td>
<td>Emergency Brake is to be initiated by all vehicles, and shall initiate a brake application at the emergency rate. Emergency brake can also be initiated by the lead vehicle when commanded by the engineer, or when the brake control system detects an emergency condition.</td>
</tr>
<tr>
<td>40</td>
<td>Section 12</td>
<td>12.1</td>
<td>1 of section 12</td>
<td></td>
<td>Specification of mobile communication system “MCP-System-3”, “MCP SEPTA”. Would SEPTA also consider the use of other communication systems between vehicle and landside, for example Witronix</td>
<td>The MCP system is required as it is integral to the design of the SEPTA PTC system. It contains the PTC data radio, along with the necessary filters and routing equipment to connect devices such as the PTC On-Board Computer, the PTC data radio, and the Event Recorder. Additional communications systems distinct from the MCP-System-3 and MCP-SEPTA parts (which are to be used solely for PTC purposes) are required to provide the non-PTC wireless download functions between vehicle and landside. SEPTA will consider all communication systems which implement the specification required functionality, with the exception of those used for the PTC system.</td>
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<td>Change #</td>
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<tr>
<td>1</td>
<td>Jumper Cables</td>
<td>TS 2.2.13.1</td>
<td>13</td>
<td>Removed requirement for use of SEPTA standard length jumper cables.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Car Hot Journal</td>
<td>TS 2.2.13.3</td>
<td>15</td>
<td>Removed requirement for car hot journal indication.</td>
<td></td>
<td></td>
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<td>3</td>
<td>IWS Test Location</td>
<td>TS 10.16</td>
<td>19</td>
<td>Changed location of IWS testing from TTC in Pueblo and Amtrak to SEPTA or Amtrak.</td>
<td></td>
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<td>4</td>
<td>Parking Brake Control</td>
<td>TS 11.1.8</td>
<td>3</td>
<td>Removed requirement for consist parking brake function to be controlled by the active cab.</td>
<td></td>
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<tr>
<td>5</td>
<td>Parking Brake Control</td>
<td>TS 11.6</td>
<td>15</td>
<td>Removed requirement for consist parking brake function to be controlled by the active cab.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Parking Brake Indicator</td>
<td>TS 11.6</td>
<td>15</td>
<td>Removed requirement for separate indication of parking brake status in controlling cab.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Pre-Production Test References</td>
<td>TS 16.5.1</td>
<td>7 &amp; 8</td>
<td>Corrected various pre-production test references.</td>
<td></td>
<td></td>
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2 DESIGN CRITERIA AND REQUIREMENTS

2.1 GENERAL

2.1.1 Human Engineering

The Locomotive design shall be based on human factors engineering. Special emphasis shall be placed on all vehicle interactions with members of the train crew, in order to maximize their effectiveness, comfort and efficiency. All switches and controls shall be designed for ease of logical use. The cab shall be spacious, well insulated from sound, and arranged to have the most ergonomic layout possible to avoid repetitive motion injury. Exterior safety appliances shall be designed for maximum ease of use.

The design of the cab, train crew controls area, vehicle maintenance locations and other crew areas shall accommodate the 5th percentile female to 95th percentile male of current United States adult general population anthropometric data, with normal vision and hearing. Specifics may be found in "Humanscale 1/2/3, 4/5/6, 7/8/9" (3 volumes), by Different, Tilley, Harman and Bardagji of Henry Dreyfuss Associates (published by MIT Press, Cambridge, MA).

2.1.2 Metrication

It is the desire of the SEPTA Railroad Division that the designs, components and fasteners used on the new vehicle be of United States inch-standards wherever possible. While use of ISO metric standards will be permitted where necessary, requests for their usage, defined at the subcomponent level, must be submitted to the Engineer for review and tracking.

As a general requirement, each major system on the car shall be designed and manufactured to a single standard (either inch or metric), and there shall not be a mixture of inch and metric parts or fasteners within any enclosure or on any component or subassembly for a major system. The carbody shall be designed to inch-standard, and all components and fasteners used in its construction shall be of that standard, unless otherwise approved by the Engineer. Due to the inability to source replacement material in the United States in metric thickness, all metal sheet and plate material used in construction of the carbody shell shall be specified on drawings and bill of materials in inch-standard thickness.

Subsystems and components affixed to the carbody or the truck shall use either unified inch screw thread fasteners, or fasteners of the same standard as used on the affixed apparatus. All drawings, manuals and publications which use metric quantities shall also include the equivalent inch-standard dimension quantity ("dual-dimension"). The Contractor shall ensure that the application of any metric fasteners used in the car or on any subsystem is coordinated so as to use the minimum number of different fasteners.
2.1.3 Design Life

The vehicle shall be designed and manufactured to perform satisfactorily for a minimum of 30 years. The carbody and all its structural elements, including trucks and running gear, shall have a minimum design life of 30 years of operation. The design and the selection of materials shall prevent corrosion damage, including the effects of winter station ice/snow melting salt, during the 30 year design life.

2.1.4 Maintenance Periods

Safety, reliability and ease of maintenance shall be the primary design consideration as referenced to Sections 2.7 and 2.8. No component shall require periodic maintenance any more frequently than 184 days nor overhauled more frequently than 5 years. Consumables, such as brake shoes/pads, are needed on an “as required” basis. Air filters shall be of a size to allow change out at periods of no less than 92 days.

Subsystems shall be selected for maximum endurance between inspections, and for ease and quickness of inspection. Locomotive structure and equipment shall not require periodic underframe washing to obtain proper functioning, long life, or to avoid corrosion.

2.1.5 Equipment Access

All locomotive equipment which requires inspection or maintenance must be readily accessible and replaceable. All underfloor equipment where possible shall be arranged to provide simple, easy access from the side of the locomotive. Major equipment shall not be located outboard of the trucks if possible, due to the increased possibility of accident and debris damage in this location. If maintenance pit access is required, special attention shall be given for access such that opened covers, access doors, etc., provide sufficient room for a maintainer to stand within the running rails of the pit. Any equipment which requires crew attention or access in the event of an emergency during locomotive operation, unless otherwise specified, shall be accessible from the locomotive interior. If approved by the Engineer on a case-by-case basis, access from the side of the locomotive may be used. In general, frequency of required service shall determine the degree of equipment accessibility. The Contractor shall prepare for Engineer approval during the initial Design Review sessions a tabulation of all controls or resets which an Operator may need to access in order to restore a disabled locomotive or train to service.

2.1.6 Interchangeability

Locomotives shall be designed and manufactured to be identical in respect to configuration, individual parts and as subassemblies. Model numbers for identical components shall be identical. Replaceable components of any such apparatus shall be fully interchangeable, without adjustments to any part or system being necessary. Microprocessor hardware units which are physically identical except for the software shall have identical part numbers. An Engineer approved subpart number may be used to identify differences by software. Such units which require location-specific module inputs shall have this performed by locomotive body wiring configuration, and not by the use of DIP switches or similar. Specific approval shall be obtained from the Engineer during Design Review or each part whose
replacement may require an adjustment, and such approval may be granted only where it can be shown to be absolutely necessary.

2.1.7 Locomotive Numbers

Locomotives covered under this Technical Specification shall be numbered as a 6400 series, starting with the Pilot Locomotive as being 6401.

2.2 DESIGN CONSIDERATIONS

1. The locomotive shall be an electric type with an overhead power collection system capable of developing the power necessary for traction per Section 9 and auxiliaries and HEP per Section 8.

2. An independent, HEP converter system shall provide 1000 kW, 480 VAC, 60 Hz, 3 phase electrical power for heating, air conditioning, and other passenger conveniences.

3. Regenerative blended dynamic brakes shall be included.

2.2.1 Ratings – Primary Voltages/Frequency Variations

The locomotive shall develop rated horsepower while in propulsion when operating under the following voltages and frequencies:

- 25 Hz System – 9.0 kV to 13.5 kV, nominal 12.0 kV with diminished performance below 11.5 kV down to the minimum operating voltage of 9.0 kV. The locomotive shall operate as specified without degradation with a voltage sine wave-form up to 40% total harmonic distortion. Additional harmonic distortion data may be supplied by SEPTA for confirmation by the Contractor.

- 60 Hz System – 9.0 kV to 14 kV, nominal 12.5 kV with diminished performance below 12.5 kV down to the minimum operating voltage of 9.0 kV. The locomotive shall operate as specified without degradation with a voltage sine wave-form up to 5% total harmonic distortion, or with distortion as may be found on the Amtrak Northeast Corridor, whichever is more stringent. Additional harmonic distortion data may be supplied by SEPTA for confirmation by the Contractor.

- 60 Hz System – 17.5 kV to 27.5 kV, nominal 25.0 kV with diminished performance below 20.0 kV down to the minimum operating voltage of 17.5 kV. The locomotive shall operate as specified without degradation with a voltage sine wave-form up to 5% total harmonic distortion, whichever is more stringent. For a primary voltage decrease between 20.0kV and 17.5kV, the power shall be reduced proportionally. Additional harmonic distortion data may be supplied by SEPTA for confirmation by the Contractor.
2.2.2 Operation

The locomotive shall be capable of operation at maximum allowable speed on trackage which meets only the minimum requirements of the FRA Track Safety Standards (49 CFR 213) for each class of track based on:

- Diameter of Wheels: 44 in. maximum
- Gearing: To be geared for a top service speed of 125 mph

Locomotives shall be designed to operate over the following curves:

1. Any horizontal curve of radius equal to or greater than 250 feet.
2. No. 8 crossovers on 12-foot track centers.
3. No. 7 crossovers on 13-foot track centers.
4. Facing No. 8 turnouts arranged to form a "S" curve with a minimum of 5 feet of tangent between switch points.
5. Two 400-foot radius reverse curves with zero tangent in-between.
6. 2000 ft. vertical curve (main line).
7. 1600 ft. vertical curve (yard, with no passengers and functioning primary suspension).

The locomotive shall be designed for high-speed operation on tangent track, and on curves having curvatures up to and including six degrees, at minimum design cant deficiency per Section 2.2.9.

During operation over these limits there shall be no metal to metal contact of truck stops or components.

Under all operating conditions, including worn wheels and broken springs, the proposed locomotive shall comply in all respects, including all projecting appurtenances, with Amtrak clearance diagram, A-05-1355 Rev E, and SEPTA clearance diagram B-4163. Where any conflict exists between these two drawings, the more stringent requirement shall apply. The Contractor shall prepare and submit for approval an analysis of the locomotive clearance with all possible combinations of failed suspension elements indicated.

Under the most unfavorable conditions of track curvature, track geometry (allowed by the FRA Track Safety Standards), wheel wear, broken springs, as well as lateral and vertical motion and roll, a clearance of at least half inch (1/2"), exclusive of positive stops, shall be maintained between truck parts and carbody parts.

Under the most restrictive track conditions and maximum buff loading, the clearance between two (2) coupled locomotives, coupled in any orientation, shall not be less than three inches (3"), except at buffers, couplers, and side barrier fixtures.
For determining vertical clearances due to wheel wear, the decrease in wheel diameter shall be from new condition to worn wheel condition as defined by the manufacturer.

2.2.3 Weights and Supplies

2.2.3.1 Locomotives

Maximum weight for electric locomotives shall be 218,000 pounds, with no more than 2% weight variance between trucks; corresponding to a maximum axle load of 54,600 pounds. Weight distribution shall be within the tolerances of Section 2.2.3.2.

Dynamic forces shall be calculated using a dynamic simulator or the British Rail method for dynamic vertical forces in combination with an approved published method for calculating dynamic lateral forces, or other published method as approved by SEPTA. If a dynamic simulation is used, the model used shall be subject to approval by SEPTA prior to performing the analysis.

2.2.3.2 Trucks and Underfloor Equipment

The locomotive body and attached equipment shall be designed to provide positive clearance for the trucks under worst case operating conditions except for any stops attached to the locomotive body for the purpose of limiting truck movement in case of derailment. Worst case conditions will result from such factors as horizontal and vertical curves, track super elevation, worn wheels, sway, derailment, suspension system failures, etc., either singly or in combination. Sufficient clearance shall be provided in the truck areas such that if one axle of the locomotive is lowered 8 inches, as in a derailment, there shall not be contact with any wheel by any part of the locomotive when air springs are deflated. All underfloor mounted equipment, unless otherwise required, shall clear the running rails under normal conditions by a minimum height of 8 inches to prevent excessive damage during a derailment.

2.2.3.3 Clearance Diagram

The locomotive design and construction shall conform to Amtrak Clearance Diagram D-05-1355, Rev. E under the worst case combination of dynamic excursion, wear, and failure of any one suspension element.

The Contractor shall prepare and submit for approval an analysis of the locomotive clearance with all possible combinations of failed suspension elements indicated.

2.2.3.4 Locomotive Balance and Weight Distribution

Locomotive design and equipment arrangement shall minimize lateral and end-to-end imbalance. Lateral imbalance shall not exceed 30,000 inch-pounds with the locomotive in ready to run condition, all provisions at 50% of capacity. End-to-end imbalance shall not exceed 3% of the total weight. Imbalances caused by variability in provisions shall not be considered in the application of weight and balance requirements.
2.2.3.5 Sand Capacity

Sand Capacity shall be 8 cubic feet, minimum, at each end.

2.2.4 Safety Appliances

All steps, grab irons, and other safety appliances (including connection/mounting styles) must comply with Federal Railroad Administration requirements.

2.2.5 Environmental Factors

The locomotives shall be designed and constructed to operate successfully under the environmental conditions present in the Continental U.S. Locomotive systems affected by extremes in climate conditions shall be designed to account for the following, at a minimum:

1. Maximum ambient temperature: 115°FDB
2. Minimum ambient temperature: -22°FDB
3. Relative humidity is between 20 and 100 percent
4. Maximum rainfall in 24 hours: 10.36 inches
5. Maximum snowfall in 24 hours: 23.6 inches
6. Maximum wind velocity
   * Sustained lateral wind (1 min) 100 mph (operational)
   * Gusting (3 seconds) 120 mph (storage)

The temperatures above represent only ambient conditions. The ambient is defined as the temperature, humidity, and environment of the area around the locomotive. Actual temperatures and conditions within the equipment compartment, or above or under the locomotive, may be more severe and can reach 150°FDB.

The effect of increased temperature due to solar radiation on the locomotive and heat produced during operation of equipment under the extreme conditions shall not result in degradation of equipment performance or reduced reliability levels. Additionally, the effects of prolonged exposure to low temperature extreme or wind shall not result in degradation of equipment performance or reduced reliability levels.

Conditions for design of heating and air conditioning systems shall be in accordance with Section 6.1.3.

The locomotive shall operate as specified in the Continental U.S. environment, which includes operation in the salt-laden atmosphere along oceans and through areas with heavy industrial air and water pollution. The most common contaminants are silica, iron, carbon, oil vapor, water vapor, ozone,
copper, nitrous oxide, hydrogen sulfide, sodium chloride, fuel oil, and both alkaline and acidic cleaning solutions.

### 2.2.6 Electronic Equipment Design Requirements

Electronic equipment shall conform to IEEE STD 16-2004 and EN 50155, unless otherwise approved by SEPTA. All type tests shall be performed.

### 2.2.7 Performance Requirements

#### 2.2.7.1 Design Speeds

The Contractor shall design and construct the electric locomotives for operation at the following speeds:

1. Maximum revenue service speed with fully worn wheels: 125 mph.

Mechanical overspeed shall be set five percent greater than the maximum design speed.

#### 2.2.7.2 Acceleration Rates

Acceleration rates suitable to cover five (5) miles in five (5) minutes, and ten (10) miles in seven and one-half (7½) minutes from a standing start, with a seven (7) car consist of 160,000 lbs per car. The locomotive shall be capable of pulling a maximum of 14 passenger cars while providing 1,000 KW of HEP.

#### 2.2.7.3 Brake Performance

Brake performance requirements described in this Section shall apply to the operation of a single locomotive with consist sizes from a minimum of three and up to a maximum of 14 passenger cars. It shall be assumed that the passenger cars just meet the minimum specified performances, with net zero effect on locomotive braking requirements. It should be noted that in certain areas where SEPTA trains operate the overhead supply system may not be able to accept regenerated power. Consequently, the locomotives shall be able to meet all braking requirements assuming that the overhead line is non-receptive.

Contractor shall provide full service and stop emergency distance curves for:

A. Entry speeds of 135 mph, with 4 passenger car consist, average car weight of 160,000 lbs. (including passengers).

B. Entry speed of 125, 110, 90, 70, 50 and 30 mph with 3 and 7 passenger car consists, average car weight of 160,000 lbs.
C. Entry speed of 100, 90, 70, 50 and 30 mph with 14 passenger car consist, average car weight of 160,000 lbs.

D. Entry speed of 90 mph for a single locomotive.

2.2.7.4 Braking Criteria - General

The specified brake performance shall be subject to the following:

1. All performance requirements shall apply for trailing loads up to and including the maximum train lengths specified in Section 2.2.7.3;

2. Unless otherwise specified, maximum stop distances shall be achieved on dry rail and level, tangent track;

3. All specified brake performance requirements shall be met without electro-pneumatic propagation;

4. Service brake shall be either all-friction or fully-blended electric and friction brakes;

5. Speed taper shall be permitted in service and emergency braking, if required, but all performance requirements shall be met throughout the stop.

6. The rate of change in deceleration (jerk rate) during service braking shall not exceed 1.5 mphpsps, including final stop. Jerk rate limitations shall not apply in emergency braking.

The Contractor shall perform, and submit for approval, a safe brake distance calculation for the locomotive and specified consists. This calculation shall consider the response time of the engineer, the brake system, the propulsion system and the cab signal and ATC systems. The calculations shall consider the achievable brake rates considering slippery rails and wheel slide correction efficiency. The calculations shall include failure modes, such as friction and electric brake failures, and demonstrate that the locomotives meet SEPTA's signaling design requirements under worst-case operating conditions.

2.2.7.5 Braking Response

Brake tractive effort build-up and release times shall meet the following criteria from time of control handle movement:

1. Full Service Application - (95% of commanded brake):
   a. 6.5 seconds maximum - train length, 3-6 cars
   b. 13 seconds maximum - train length, 18 cars

2. Full Service Release - (5 PSI BCP)
2.2.7.6 Service Braking - Maximum Stop Distance Requirements

The following maximum stop distance shall be achieved with the specified unloaded consists, worst case, locomotive leading. Stop distances are to be measured between the first motion of the brake handle and the moment that the vehicle reaches standstill.

<table>
<thead>
<tr>
<th>Entry Speed</th>
<th>Stop Distance</th>
<th>Max. I instantaneous Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>125 mph</td>
<td>7,717 ft</td>
<td>2.5 mph/s</td>
</tr>
</tbody>
</table>

Below 125 mph entry speed, the average deceleration rate measured from time of control handle movement of the train consist to stop shall not be less than 1.6 mph/s and the maximum instantaneous brake rate shall not exceed 2.5 mph/s. Stopping distances for brake commands less than full service shall increase linearly (±30%) between commands for full service and minimum brake applications.

2.2.7.7 Emergency Braking - Maximum Stop Distance Requirements

The following maximum stop distances shall be achieved with the specified consists, worst case.

<table>
<thead>
<tr>
<th>Entry Speed</th>
<th>Stop Distance</th>
<th>Max. Instantaneous Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>125 mph</td>
<td>5,525 ft</td>
<td>2.7 mph/s</td>
</tr>
</tbody>
</table>

Below 125 mph entry speed, the average deceleration rate measured from time of control handle movement to stop shall not be less than 1.9 mph/s and the maximum instantaneous brake rate shall not exceed 2.7 mph/s.

2.2.7.8 Thermal Capacity Requirements

The locomotive friction brake system shall have sufficient power-dissipating capability to permit unrestricted operation. In the event that blended braking is not available due to the electric brake being cut out, the friction brake system shall permit continued unrestricted revenue-service operation at scheduled speed with the consists specified to the terminal point.

During all locomotive operating conditions, the following requirements shall be met:

1. Disc temperatures shall not exceed the limits recommended by the manufacturer;
2. Brake pad and brake shoe temperatures shall not exceed the limits recommended by the manufacturer;

3. No locomotive components shall be exposed to excessive heating due to the friction brake system.

To demonstrate compliance, a dynamometer test and a road test shall be performed simulating unrestricted scheduled service, operation with all friction braking, a fully loaded locomotive and 3-car consist as specified and 15% of the friction brake equipment inoperative.

Thermal capacity shall be separately validated at design operating speed and duty profiles. Both the thermal and friction capabilities of the friction brake system shall be subject to critical review at design operating speeds and duty profiles.

2.2.8 Propulsion System

2.2.8.1 Supply Voltages

The electric locomotive shall operate on the following nominal AC voltages supplied via overhead catenary: 25 kV, 60 Hz; 12.5 kV, 60 Hz; and 12 kV, 25 Hz.

Locomotives shall meet all schedule performance requirements with a catenary supply voltage in the range defined in table 9-1 for specified performance, while maintaining the schedule performance requirements of Section 2.2.7.2.

Equipment design shall take into account the harmonic content of the catenary system voltages and currents. The catenary system is supplied by both rotary and static frequency converters. Harmonics that are generated by traction loads on the system shall also be considered. Measurement of the system harmonics are required by the Contractor on SEPTA’s West Trenton Line and Airport Line.

2.2.8.2 Rating

The electric locomotive rating shall be established with sufficient horsepower to provide continuous 125 mph operation when used in a train consist of one (1) locomotive and 7 cars with an average weight of 160,000 lbs. each and 1000 KW HEP load.

The Contractor shall furnish the following information based on 95°F, sea-level altitude, level, tangent track, no wind factor:

1. Locomotive Rail Horsepower from 0-125 mph;

2. Dynamic/Regenerative Brake Characteristics from 125-0 mph;

3. Tractive Effort for both short-time and continuous ratings, 0-125 mph;

4. Speed vs. Time, Speed vs. Distance, Time vs. Distance;
5. Pneumatic and blended service and emergency braking curves;

6. Speed vs. Power Factor at full power, at 25 kV-60 Hz, 12.5 kV-60 Hz and 12 kV-25 Hz;


The Contractor shall include a minimum of 10 percent margin in the sizing of the thermal capacity of the main transformer, a minimum of 15 percent margin in the sizing of the thermal capacity of the traction motors, a minimum of 15 percent margin in the sizing of the thermal capacity of the input rectifier, and a minimum 20 percent margin in the sizing of the thermal capacity of the remainder of the propulsion equipment and its associated cooling system. The above margins assume the following in addition to the preceding criteria:

1. 6 inch cant deficiency;

2. Restricted catenary voltage shall be met in accordance with Table 9.1 in Section 9.

The locomotive shall support a continuous Wilmington – Philadelphia – Trenton duty cycle, making all local stops, allowing for a 0.5-hour turnaround at terminals. Each locomotive shall be capable of operating at a reduced level of performance and without damage with the loss of one major propulsion component (excluding the main transformer), and with consist sizes of up to 14 cars at 160,000 lbs each, over the entire corridor route. The Contractor shall advise SEPTA of the starting capabilities of such electric locomotive.

The Control system redundancy shall support movement of the locomotive at reduced performance after component or computer failure. The locomotive shall be fully protected by the microprocessor control system against operational overloads and component failures. Full diagnostics and defect location shall be provided.

### 2.2.9 Cant Deficiency

The design cant deficiency shall be nine inches; revenue operations shall be conducted at a maximum of six inches cant deficiency.

The Contractor shall provide analysis and test data indicating the location of the force vector resultant at 1" increments in levels of superelevation for operation up to 9 inches of cant. Therefore, in the case that the static lean is at 9 inches of superelevation, the lightest wheel must have at least 60% of its static load remaining. In the dynamic case, the lightest wheel must have at least 10% of its static load remaining. (Any changes in these values as a result of the enactment of new regulations shall be the subject of design review.)
2.2.10 Route Characteristic and Track Condition Data

2.2.10.1 West Trenton Route
Track geometry data for SEPTA’s West Trenton Line shall be provided to the Contractor after Notice-to-Proceed for purposes of truck and suspension design. Data shall be recorded on electronic means.

2.2.10.2 Philadelphia-Harrisburg Route
Track geometry data for the Philadelphia - Harrisburg rail line shall be provided to the Contractor after Notice-to-Proceed for purposes of truck and suspension design. Data shall be provided by electronic means.

2.2.10.3 Track Geometry
Track Geometry shall meet the operational requirements of Section 2.2.7.2

2.2.11 Structural Strength
As a minimum, the locomotive shall comply with all FRA regulations and AAR standards for the design of locomotive car bodies in accordance with CFR 49 Parts 229, 238 and AAR S580.

2.2.12 Operating Requirements

2.2.12.1.1 Operating Cabs
The locomotive shall be bi-directional and shall be equipped with a fully functional operating cab at each end.

2.2.12.2 Multiple Train Operation
Unrestricted, full performance multiple-unit operation shall be possible from the lead cab of a two-unit locomotive consist.

Pantograph mounting shall be centered over the trucks.

2.2.12.3 Compatibility with Other Rolling Stock
The locomotive shall be mechanically and electrically (HEP, Communication and MU) compatible with any combination of SEPTA coach and cab cars. The locomotive may operate lead, trail, or push-pull with MU control from a cab car and shall be able to operate connected to all standard or fixed cables on SEPTA rolling stock.
Couplers, (including air connections) brakes hoses, and trainline electrical cables shall interface directly with SEPTA Bombardier coach and cab cars in a manner which shall permit safe operation of train consists with any mixture of the car types. Electrical receptacles, as well as plug location and length, shall interface directly with present SEPTA equipment.

The locomotive hauling coaches shall be able to negotiate worst curve and track conditions specified in Section 2.2.10.3. The coach and locomotive draft gear travel shall be considered.

2.2.13 Trainlines

Trainline cables provide both HEP and control to/ between the locomotive(s) and the train. One set of the following jumper cables shall be provided per locomotive:

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Cables</th>
<th>Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>480VAC jumper cables</td>
<td>The four cables in parallel provide a means to distribute 480VAC, 3-phase, 60 Hz power, generated on the locomotive (or from a wayside power source), to be transmitted throughout the train to power auxiliary equipment</td>
</tr>
<tr>
<td>1</td>
<td>27 point communication jumper cable</td>
<td>This trainline system employs APTA conventional-style system to carry car control &amp; indication throughout the train</td>
</tr>
<tr>
<td>1</td>
<td>27 point MU jumper cable (only when train is in Push-pull operation)</td>
<td>This trainline system employs APTA conventional-style systems to carry traction control between locomotives and/or with a cab car</td>
</tr>
</tbody>
</table>

The trainline systems shall be mechanically and electrically compatible with all the following SEPTA equipment:

- HSEL
- All single level SEPTA Bombardier Coach and Cab cars
- Wayside 480VAC power at SEPTA Frazer Shop

2.2.13.1 Receptacle Locations on Locomotive Ends

Receptacles of each type shall be installed on all four corners of the locomotive to allow locomotives to turned randomly end-for-end in a consist. In order to use SEPTA standard length jumper cables between locomotives as well as to adjacent cars, the location of the receptacles in all three axes must be coordinated with those of existing SEPTA equipment.
27-point jumpers and receptacles are labeled and color-coded as well as keyed to prevent cross-connection. Communication trainline receptacles and jumper heads shall be colored medium blue. MU trainline receptacles and jumper heads shall be colored black.

In all normal operations, a single 71" communication jumper cable is connected between the locomotive and adjacent car as well as between locomotives when double-headed. Likewise, in Push-Pull operation a single 71" MU jumper cable is connected between the locomotive and adjacent car as well as between locomotives when double-headed.

MU trainline and communication trainline jumpers and receptacles shall be designed and located so that they shall permit movement of the vehicles, coupled to one another or to a locomotive, over the curves and crossovers specified in Section 2.2.10.3 without exposing the lower end of the jumper loops to damage. Jumpers and receptacles shall be located as near as possible to the underside of the end sill, but not higher than 48 inches above the top of rail.

All connections between door control/communication trainline jumpers and receptacles and their corresponding trainline conductors shall be made in a watertight junction box, by means of terminal blocks. Junction boxes shall be located and constructed so as to afford convenient access by maintenance personnel.

### 2.2.13.2 Communication Trainline

This trainline is primarily responsible for functions with the passenger car portion of the train; however several indications are conveyed to the locomotive as well. All 27 wires are carried to and through the locomotive, even though not all are connected to locomotive equipment. Male receptacle assemblies Clements National CRA-27-AMTK, or equal, shall be provided at both ends of the vehicle. The pin assignments shall be compatible with the SEPTA push-pull vehicles previously supplied by Bombardier:

<table>
<thead>
<tr>
<th>Pin No.</th>
<th>Function</th>
<th>Marker</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Shield</td>
<td>SH</td>
<td>12</td>
</tr>
<tr>
<td>2</td>
<td>Car Battery Negative</td>
<td>BN</td>
<td>10</td>
</tr>
<tr>
<td>3</td>
<td>Public Address Audio 1</td>
<td>PA1</td>
<td>12 Shielded</td>
</tr>
<tr>
<td>4</td>
<td>Public Address Audio 1</td>
<td>PA2</td>
<td>12 Shielded</td>
</tr>
<tr>
<td>5</td>
<td>Intercom</td>
<td>PA3</td>
<td>12 Shielded</td>
</tr>
<tr>
<td>6</td>
<td>Intercom</td>
<td>PA4</td>
<td>12 Shielded</td>
</tr>
<tr>
<td>7</td>
<td>Public Address Control</td>
<td>PA5</td>
<td>12</td>
</tr>
<tr>
<td>8</td>
<td>Public Address Control</td>
<td>PA6</td>
<td>12</td>
</tr>
<tr>
<td>9</td>
<td>Radio</td>
<td>RA1</td>
<td>12 Shielded</td>
</tr>
<tr>
<td>10</td>
<td>Radio</td>
<td>RA2</td>
<td>12 Shielded</td>
</tr>
<tr>
<td>11</td>
<td>Snow Brake</td>
<td>SB</td>
<td>12</td>
</tr>
<tr>
<td>12</td>
<td>Doors Open – Right Side Low Level</td>
<td>DORL</td>
<td>12</td>
</tr>
<tr>
<td>13</td>
<td>Doors Open - Right Side High Level</td>
<td>DORH</td>
<td>12</td>
</tr>
<tr>
<td>14</td>
<td>Doors Open - Right Side</td>
<td>AOB</td>
<td>12</td>
</tr>
</tbody>
</table>
### 2.2.13.3 27-Point Communication Trainline Indicators on Operator’s Console

The following indications shall be provided, each equipped with a self-test feature or the following indications may also be integrated on the cab screen:

<table>
<thead>
<tr>
<th>INDICATOR GROUP</th>
<th>CONDITION</th>
<th>INDICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Train status</td>
<td>Brakes applied</td>
<td>Amber</td>
</tr>
<tr>
<td></td>
<td>Brakes released</td>
<td>Green</td>
</tr>
<tr>
<td></td>
<td>Car doors closed</td>
<td>Green</td>
</tr>
<tr>
<td></td>
<td>Car door override</td>
<td>Red</td>
</tr>
<tr>
<td></td>
<td><strong>Car hot Journal</strong></td>
<td>Red</td>
</tr>
<tr>
<td></td>
<td>Spare</td>
<td>Red</td>
</tr>
</tbody>
</table>

### 2.2.13.4 Audible Alarms associated with Communication Trainline

The 4.5 kHz continuous tone audible alarm shall be provided for the Conductor signal.

### 2.2.13.5 MU Trainlines

These trainlines carry traction commands and indications between double-headed locomotives as well as the cab car operator cab and the locomotive.

Configuration:

- 27 Conductor trainline
- 74 VDC nominal voltage, ungrounded
- Voltage source from locomotive
- On/off commands & indications

The HSEL locomotive shall be operable under MU situations with another HSEL locomotive or cab cars with either in the lead position.

The following shall be integrated into the propulsion control 27 point MU trainline operation:

A. # 2 Trainline (alarm):
   Faults which trigger this alarm include:
   - Main circuit breaker open by manual opening
   - Fault condition resulting in automatic MCB opening
   - HEP shutdown (other than by command)

B. # 26 trainline
   A push button will be provided to apply 74 volts to this trainline to reset the locomotive. The pushbutton shall be labeled "Trainline Ground/EAB Alarm Silence". It is also used to reset the electronic air brake fault alarm.

2.2.13.6 Black MU Receptacle

On all four corners of the locomotive there will be one black 27-point receptacle, Clements National CRA-27-MU-BK, or equal, providing MU trainline control to and from the locomotive.

The pin assignments shall be compatible with the SEPTA push-pull vehicles previously supplied by Bombardier:

**Locomotive Control Trainline**

<table>
<thead>
<tr>
<th>Pin</th>
<th>Function</th>
<th>Marker</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>VC 11KV - 25Hz</td>
<td>VC1</td>
<td>12</td>
</tr>
<tr>
<td>2</td>
<td>Alarm</td>
<td>SG</td>
<td>12</td>
</tr>
<tr>
<td>3</td>
<td>D Valve</td>
<td>DV</td>
<td>12</td>
</tr>
<tr>
<td>4</td>
<td>Negative</td>
<td>N</td>
<td>10</td>
</tr>
<tr>
<td>5</td>
<td>Emergency Sanding</td>
<td>ES</td>
<td>12</td>
</tr>
<tr>
<td>6</td>
<td>Generator Field</td>
<td>GF</td>
<td>12</td>
</tr>
<tr>
<td>7</td>
<td>C Valve</td>
<td>CV</td>
<td>12</td>
</tr>
<tr>
<td>8</td>
<td>Reverse (A end)**</td>
<td>RE</td>
<td>12</td>
</tr>
<tr>
<td>8</td>
<td>Forward (B end)**</td>
<td>FO</td>
<td>12</td>
</tr>
<tr>
<td>9</td>
<td>Forward (A end)**</td>
<td>FO</td>
<td>12</td>
</tr>
<tr>
<td>9</td>
<td>Reverse (B end)**</td>
<td>RE</td>
<td>12</td>
</tr>
<tr>
<td>10</td>
<td>Wheel Slip</td>
<td>WS</td>
<td>12</td>
</tr>
<tr>
<td>11</td>
<td>Auto Power Reduction</td>
<td>APR</td>
<td>12</td>
</tr>
<tr>
<td>Pin</td>
<td>Function</td>
<td>Marker</td>
<td>Size</td>
</tr>
<tr>
<td>-----</td>
<td>-----------------------------</td>
<td>--------</td>
<td>------</td>
</tr>
<tr>
<td>12</td>
<td>B Valve</td>
<td>BV</td>
<td>12</td>
</tr>
<tr>
<td>13</td>
<td>Positive Control</td>
<td>PC</td>
<td>10</td>
</tr>
<tr>
<td>14</td>
<td>Pantograph Down</td>
<td>P.D.</td>
<td>12</td>
</tr>
<tr>
<td>15</td>
<td>A Valve</td>
<td>AV</td>
<td>12</td>
</tr>
<tr>
<td>16</td>
<td>Engine Run</td>
<td>ER</td>
<td>12</td>
</tr>
<tr>
<td>17</td>
<td>Pantograph Up</td>
<td>PU.</td>
<td>12</td>
</tr>
<tr>
<td>18</td>
<td>VC 25 KV - 60 Hz</td>
<td>VC</td>
<td>12</td>
</tr>
<tr>
<td>19</td>
<td>Excessive Current</td>
<td>E.C.</td>
<td>12</td>
</tr>
<tr>
<td>20</td>
<td>Brake Warning</td>
<td>BW</td>
<td>12</td>
</tr>
<tr>
<td>21</td>
<td>Brake System Negative</td>
<td>BN.</td>
<td>12</td>
</tr>
<tr>
<td>22</td>
<td>Emergency Brake</td>
<td>EM.</td>
<td>12</td>
</tr>
<tr>
<td>23</td>
<td>Manual Sanding</td>
<td>MS</td>
<td>12</td>
</tr>
<tr>
<td>24</td>
<td>Brake Application</td>
<td>BA.</td>
<td>12</td>
</tr>
<tr>
<td>25</td>
<td>Brake Release</td>
<td>BR.</td>
<td>10</td>
</tr>
<tr>
<td>26</td>
<td>Reset Fault</td>
<td>RF</td>
<td>12</td>
</tr>
<tr>
<td>27</td>
<td>No Power Brake</td>
<td>NPB</td>
<td>12</td>
</tr>
</tbody>
</table>

** Wires cross in jumper.

### 2.2.13.7 Cab car operation:

In cab car operation, the cab car’s MU trainline functions receive their power from the locomotive, (# 13 & #4 pins) not the cab car. Power as well as MU information is conveyed via the Black 27 MU Receptacle and trainline. Note: The locomotive 74Vdc electrical system is kept isolated from the 74Vdc car electrical system.

### 2.2.13.8 Cab Switch Panels

Setup switches etc. will be mounted on a panel in the cab, accessible to the seated operator. All devices will be clearly labeled by name and position. A label will be included which provides instructions for switch and circuit breaker positions for lead and cutout operation. All labeling on the locomotive is subject to review for acceptance by SEPTA.

Switches shall include at a minimum:

- Door interlock bypass switch (sealed)
- 13T push/pull

A switch, labeled 13T push/pull shall be provided in cab overhead Engineer’s side to allow locomotive 74Vdc power to be provided to the # 13 trainline wire when the locomotive is operating in push (-pull) mode. Power provided via the MU trainline is used by the cab car to control MU functions back to the locomotive. A 15 amp circuit breaker is located in the cab car to serve two functions:
• protect cab equipment from faults in the outgoing MU trainline system

• provide on/off switch function to activate or deactivate the (cab car) cab for changing ends

2.2.14 Digital Trainline Network (DTN)

An Ethernet Digital Train Network designed to have consistent 1Gbps of bandwidth shall be provided to facilitate networked communications throughout a consist of DTN enabled vehicles. The DTN is to be designed such that the failure of any active component or power failure within one vehicle shall not interrupt the DTN functionality for the remainder of the consist. Any failure of the DTN shall not impact the primary operation of the vehicle that is enabled by the 27-pin jumper. The design, configuration, and operation of the Digital Trainline Network shall be submitted for approval by SEPTA. The network design shall be non-proprietary.

2.2.14.1 DTN Receptacles

The locomotive shall have four DTN receptacles, two per end of the vehicle. Each receptacle shall be pre-wired with one ISO/IEC 11801 Category 7 cable for the Gigabit Ethernet network, and one ISO/IEC 11801 Category 7 cable as a spare. Cable arrangement and routing shall be such to provide EMI immunity, and to be shall be approved by SEPTA. Each receptacle is to be wired to an Ethernet switch located inside the vehicle. The receptacle design, spare assignment, orientation, and operation shall be submitted to SEPTA for review and approval. The receptacles shall be such that when cables are not plugged in self-closing covers shall prevent debris and moisture from entering.

2.2.14.2 DTN Jumper Cables

Four jumper cables shall be provided with each locomotive. The jumper cable design shall be suitable for the environment it is to be installed in, and sized according to the SEPTA track alignment and minimum turn radius. The jumper shall be designed with keyways to ensure proper mating with the trainline receptacle. In the case of a train separation without a disconnection of the jumper cable, the jumper cable shall be designed to break away without causing damage to the receptacle or vehicle body. Connection and durability of the jumper should be similar to existing 27-pin, HEP, and other digital trainline network connectors, and shall be fully removable. Both plug sides of the jumper cable shall be identical, to allow plugging in either end to either vehicle. EMI mitigation techniques such as shielding and screening shall be incorporated into the jumper design to ensure the full 1Gbps of bandwidth is consistently available while operating throughout SEPTA’s environment.

2.2.14.3 Train Ethernet Switches

Train managed Gigabit Ethernet switches shall be installed at each end of the vehicle. The Train Ethernet Switches shall be equipped with failover contacts, such that if a switch fails or power is lost, the trainlined Ethernet ports automatically bridge through to the next vehicle. Train Ethernet switches shall be configured to allow VLAN assignments to manage network traffic flow, and shall be conformant to IEEE 802.1Q. Train Ethernet switches shall be configured to utilize both receptacles when a jumper is available on each to provide redundancy by utilizing IEEE 802.3ad. The network shall remain fully functional providing consistent 1Gbps of bandwidth when only one jumper is installed.
2.2.14.4 DTN Cabling and Connectors

Two Category 7 Ethernet Cables shall be installed to connect the train switch at each end of the vehicle with each other. Cable arrangement including termination of shields, shall be submitted for SEPTA approval. Gigabit Ethernet connectors used throughout the vehicle shall be 8 pin, A-coded M-12 connectors. Fast Ethernet (100mbps) connections shall be connected utilizing 4-pin, D-coded M-12 connectors.

2.2.15 Propulsion Control 27 Point MU Trainline Operation

2.2.15.1 Power Knockout Functions

Power knockout (PKO) shall occur in response to emergency or penalty brake applications. The MU propulsion control system will receive the PKO message from the brake system and immediately remove traction power by de-energizing the GF, A, B, C & D trainlines and also lighting "PCS open" indication on the console. Operation of this interface will be subject to design review. Recovery from Penalty & Emergency application will be as detailed below:

**Traction Recovery from Emergency**
- 1. Brake handle in emergency
- 2. 60 seconds from application of emergency
- 3. Throttle to idle or dynamic brake setup
- 4. Brake handle to release
- 5. Throttle to power or dynamic brake position

**Traction Recovery from Penalty**
- 1. Brake handle to suppression
- 2. Throttle to idle or dynamic brake setup
- 3. Satisfy system that initiated penalty (e.g. acknowledge alerter)
- 4. Brake handle to release
- 5. Throttle to power or dynamic brake position

2.2.15.2 27-Point Receptacle Application to Locomotives
The following receptacles and jumper cables shall be provided at each end of each locomotive. Jumper cables shall be compliant with APTA RP-E-019-99 except as otherwise specified herein:

A. End Arrangement

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>27-Point Communication Receptacle, painted blue, complete with contact insert and wiring: Amtrak Drawing D-63-7439 Rev. B.</td>
</tr>
<tr>
<td>2</td>
<td>27-Point MU Receptacles, painted black, complete with contact insert and wiring: Amtrak Drawing D-63-7437, Rev. B</td>
</tr>
</tbody>
</table>

B. 27-Point Jumper Cable Application to Locomotives

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>27-Point Communication Jumper Cable, 71&quot; locomotive-to-locomotive-to-car: Amtrak Drawing C-01-1499, Rev. D.</td>
</tr>
<tr>
<td>1</td>
<td>27-Point MU Jumper Cable, Black, 71&quot; locomotive-to-locomotive-to-car: Amtrak Drawing C-63-7422, Rev. C.</td>
</tr>
</tbody>
</table>

C. Component Mounting

The plate to which the receptacles are mounted should be reinforced to resist, without bending, a 500 lb. force produced from pulling the locked jumper out of the receptacle, such as by an unauthorized uncoupling. The jumper cable shall be sacrificial relative to the car body components under these conditions.

The receptacles shall be mounted to the car end with stainless steel bolts, screwing into threaded metal inserts (such as weld-nuts; not press-nuts).

Receptacle mounting should be such that there is adequate clearance between jumpers, receptacles and uncoupling rods, (car) diaphragm / buffer, couplers, air hoses, etc. Variables include:

- Coupler motion horizontally and vertically
- Relative motion to adjacent vehicle, in curve, passing through crossover, in buff and draft, etc.
- Whether jumper is inserted into receptacle or not

There shall be no interference that restricts the receptacle cover from being fully opened to allow insertion or withdrawal of jumpers.

D. Labeling

Receptacles shall be labeled with embossed stainless steel ID plates with black painted characters.
2.2.15.3  27-Point Trainline Junction Boxes

Separate stainless steel waterproof junction boxes shall be provided at each end of the locomotive for the Communication and MU Trainline Systems. The inside of the box shall be painted with an insulating paint or varnish. All wires shall be terminated using AMP PIDG ring tongue lugs or SEPTA approved equal, mounted onto terminal blocks in the junction boxes. To the extent possible, the box shall be located where it is shielded from roadside debris and locomotive system drains. The box shall be equipped with a drain hole and stainless steel cotter key.

2.2.15.4  27-Point Trainline Wire Routing

Wire will be routed using rigid (heavy wall) conduit or SEPTA approved alternative between the receptacle back box and the adjacent 27-point junction box.

2.2.15.5  27-Point Trainline Wiring

Wiring connecting the 27-point receptacles from one end of the vehicle to the other shall be run in heavy wall steel conduit or equivalent.

For safety reasons, wiring of the 27-point communication, 27-point MU and 480VAC trainline control shall each be run in a dedicated rigid conduit (total of 3) between ends of the car. The following considerations shall be included in the design:

- Where trainline wires are required to cross, (such as forward and reverse wires), this should occur at the B-end (rear) of the vehicle.

- The wiring for the different types of trainline systems (MU and communication) should be mechanically separated, including separate conduits, so as to minimize the risk of EMI and to prevent accidental cross connection, either from installation or from mechanical damage sustained in service.

- The routing of the trainline cables, particularly under car, should be selected so as to ensure it is well protected from mechanical damage, especially from wayside debris.

Continuity - All like pins of the trainline cable systems should have continuity between all like receptacles, whether the function is currently in use or not.

Spare Circuit Availability - In addition, all 27 wires of each of the trainline systems shall be brought within the vehicle to suitable terminal blocks so current spares are easily available for future assignment.

Spare Wires End to End - All undesignated function pins and conductors shall be marked as spare wires and shall be installed between end-of-car junction boxes for each trainline cable system. Spare or unused wires should not be grounded.

For passenger car trainline interface detail, please refer to Amtrak Drawing No. A-63-7676-1 Rev. C.
2.2.16 480VAC HEP Trainline System

All electrical power used on the passenger cars shall be provided by the locomotive from a 480VAC, 3-phase, 60 Hz, trainlined Head End Power (HEP) source. The HEP shall be ground fault tolerant, with its neutral referenced to ground such that a solid ground fault anywhere on the consist can be tolerated, without interruption and indicated for next day maintenance.

The HEP shall be a neutral-grounded system using either a low or a high impedance ground. The ground scheme on the neutral shall allow uninterrupted HEP operation with no operator interaction, even when one power phase has a solid ground as a result of a fault condition.

When a train is double-headed, or has a locomotive on both ends, it shall be possible for either locomotive (only one at a time) to provide HEP to the train. When the consist including locomotive is in a yard or Frazer Shop, it shall also be possible to provide HEP to the train from a wayside utility style transformer source, feeding HEP to either the car or locomotive end. The end of the locomotive not coupled to the train will have looping jumpers installed between adjacent 480VAC receptacles, to complete the trainline complete circuit.

The design of the trainline complete circuit shall protect the locomotive system from damage resulting from:

- Another locomotive already applying TLC control voltage to the trainline (another HSEL, or AEM7).
- Yard/shop power trainline complete. The trainline voltage from wayside yard or shop power is 480 VAC. The locomotive trainline control voltage is 74 VDC and the design of components must be such as to prevent any damage from yard wayside power of 120 VAC control voltage.

Four jumper cables are connected from the locomotive(s) to the first car and between adjacent cars to carry the power throughout the train.

2.2.16.1 HEP System Attributes

The following attributes shall be included in the design:

- One 1600 Amp (continuous) capacity HEP bus the length of the train (see APTA RP-E-015-99, Figure 1)
- Locomotive source is 480 VAC, 3 Phase, 3 wire, grounded (high or low impedance) system
- Train load is 480 VAC, 3 Phase, 3 wire, ungrounded system
- All 4 jumpers wired in parallel
• In addition to the 3 main power conductors, the jumpers also include 3 control pins, which provide the HEP control system a trainline complete signal (indicating all jumpers throughout the train are in place), and a car-to-car carbody ground bond.

• Power schematic per APTA RP-E-015-99, Figure 2

• Control schematic per APTA RP-E-015-99, Figure 4

### 2.2.16.2 HEP load meter

HEP shall have a load meter for monitoring output voltage, frequency and current as well as total HEP trainline output.

### 2.2.16.3 480VAC Trainline Receptacle Application to Vehicles - End Arrangement

Four (4) 3/3 pole receptacles shall be provided at each end of each locomotive. Each connector shall have three main power contacts and three control contacts, and shall be supplied with, and mate with jumper cable Clements National part MPA-2-057-V01 or equal, each consisting of three (3) 4/0 single conductor cables and one (1) 3-conductor #10 cable. Storage locations shall be provided on board the locomotive for unused jumper cables. Power receptacles and jumper heads shall be labeled and color coded bright red.

The jumper plugs shall be equipped with three power points and three shorter control points. When any jumper is disconnected, the shorter control points shall break contact first, opening a contactor in the 480 VAC supply in the locomotive to prevent disconnecting the power points under load. Jumpers and receptacles shall be so designed and located that they shall permit each jumper to be inserted into the adjacent receptacle at the end of the train farthest from the locomotive to complete the control circuit.

To prevent rubbing, jumper cables shall be fabricated with a loop formed to its nominal position between vehicles.

### 2.2.16.4 HEP Connection Component Mounting

The plate to which the receptacles housings are mounted shall be reinforced to resist, without bending, a 500 lb force produced from pulling the locked jumper out of the receptacle, such as by an unintended uncoupling. The jumper cable should be sacrificial relative to the carbody components.

Jumpers and receptacles shall be designed and located so that they shall permit movement of the vehicles, coupled to any specified coach car or another locomotive of the same type, over the curves and crossovers specified in Section 2.2.10.3 without exposing the lower end of the jumper loops to damage. Jumpers and receptacles shall be located as near as possible to the underside of the end sill, but not higher than 48 inches above the top of rail.
The receptacles shall be mounted with a downward slope of approximately 15 degrees to provide drainage. Receptacles and fixed jumper flanges shall be mounted to the carbody with stainless steel bolts, and ESNA-type nuts.

Receptacle mounting should be such that there is adequate clearance between jumpers, receptacles and uncoupling rods, (car) diaphragm / buffer, coupler, air hoses, etc. Variables include:

- Coupler motion horizontally and vertically
- Combined effects of relative motion to adjacent vehicle, in curve, passing through crossover, in buff and draft, etc.
- Whether jumper is inserted into receptacle or not

There should be no interference that restricts opening the receptacle cover fully to allow insertion or withdrawal of jumpers.

**Labeling** - The 480V receptacles shall be marked with appropriate "DANGER 480V" warnings, in accordance with 49 CFR 229.85.

### 2.2.16.5 480VAC Trainline Control Junction Boxes

A corrosion-resistant junction box constructed from stainless steel equipped with screw or stud type terminal blocks shall be provided near each end of the locomotive to provide for the connecting of the receptacle control pigtails with the vehicle carbody wiring. The inside of the box shall be painted with an insulating paint or varnish. To the extent possible, the box shall be located where it is shielded from roadside debris and locomotive system drains. The insulation value at the bolted connection shall be equal to or greater than the adjacent cable insulation.

If the box is shared with 27-point receptacle wiring, the terminal blocks for different functions: HEP control, MU, car control, etc, shall be physically separate.

Individual terminals shall be permanently labeled for each specific wire name. Termination should be with vibration-resistant, ring-tongue, crimp-type lugs.

### 2.2.16.6 480VAC Trainline Power Junction Box

A power junction box or equal shall be provided on the locomotive to provide a point for the trainline cables of each phase to be connected to a common bus bar (one per phase). In addition, the box provides a point for the HEP inverter wiring to connect to the trainline wiring.

**Enclosure** - If Undercar, the waterproof enclosure shall be constructed of heavy gauge, non-magnetic stainless steel with a gasketed cover. Metallic, corrosion resistant, waterproof strain relief bushing shall be installed to provide cable entry for the 480-volt trainline conductors. The cover shall incorporate a method of providing a metal-to-metal stop so that when the cover fasteners are secured, the cover resilient seal is not crushed. The inside of the box shall be painted with an insulating paint or varnish.
Bus Bars - Three (3) copper bus bars shall be provided, one per phase, to provide a connection point for the busing of the trainline cables. The cables should be connected to the bus bars through the use of bolted, hydraulically crimped lugs. The bars should be of adequate cross sectional area for the 1600 amp trainline rating. The bus bars should be mounted via standoff insulators.

2.2.16.7 480VAC Trainline Power Cable

Each receptacle shall be connected to the Power Junction Box with 4/0 cable with a minimum voltage rating of 2000 VAC. Thus, the trainline consists of 4 – 4/0 cables in parallel per phase. The cabling may use another conductor configuration if it can be shown equivalent in capacity rating.

Cable Cleats - Trainline cable shall be supported by cleats with suitable spacing. Cleat design shall prevent crushing cables from over tightening the mounting hardware, such as by incorporating spacers within the mounting holes. Slack shall be provided in the cable to accommodate thermal expansion and contraction.

2.2.16.8 480VAC Trainline Wire Routing

The 480 VAC power conductors shall be routed to avoid sharp bends that may over stress the insulation and lead to short life. The bend radius shall not be less than the manufacturer's recommendation. The "SO" control cord shall enter the junction box through an insulated metal strain relief bushing.

Cable routing and discharge points of locomotive cooling system outlets, battery compartment drain, and other equipment shall be coordinated to avoid discharges of water, waste, etc. onto the cable and/or conduit and associated support hardware.

Subject to SEPTA approval, the Contractor shall supply a junction box at each corner of the locomotive.

The power wiring for the HEP trainline system shall be mechanically separated from other sensitive vehicle wiring so as to minimize the risk to other equipment from EMI.

The power wiring shall be run with all three (3) phases grouped together at all times. Conductors should be located to avoid local induction heating, which includes but is not limited to avoiding resting cables on magnetic materials such as undercar equipment enclosures.

Beneath the carbody, trainline cables should be routed as high as possible to minimize exposure to road impact damage.

Cable Impedance - Power cable lengths should be kept as equal as possible between the end of the locomotive and the HEP power junction box. This is to keep the impedance of each cable nearly equal in order to force current sharing among all jumpers.

TLC Circuit - The TLC circuit conductors should run in a separate conduit, terminating at each end of the vehicle in the control junction box. Only the TLC wires may occupy this conduit.
2.2.16.9 480VAC Trainline Wire and Cable Termination

The #10 AWG control conductors shall be terminated with AMP PIDG type ring tongue crimp lugs mounted onto terminal blocks in the control junction boxes. The 4/0 power conductors shall be terminated in hydraulically crimped AMP # 326803 short barrel lugs using double-bolt tongue. The completed splice shall be insulated by heavy wall heat-shrink tubing with sealant to form a waterproof joint. The splice shall be located so as to be readily disconnected with a minimum of disassembly.

2.2.16.10 480VAC HEP Source Characteristics

The locomotive shall be equipped with an inverter HEP power source meeting the following characteristics:

- 480VAC, 3 phase, 60 Hz, 1200 kVA continuous rating
- The trainline wiring system itself shall have a continuous 1600 Amp capacity.

The locomotive HEP power source, control and HEP trainline wiring shall be in compliance with APTA RP-E-015-99 “Recommended Practice for Head End Power Source Characteristics”, for a Single Bus system, except as noted below and except as formally agreed to with SEPTA. It shall meet the locomotive type requirements of section 5.4. In addition to the TLC function described in section 5.5.3, the circuit shall also incorporate a 5 mph bypass, as described in Section 8.8 of this HSEL specification. The locomotive will not be equipped with the F-end isolation switch, described in section 5.6.6. SEPTA wayside power sources, are normally rated at 800 amps. The table below indicates applicability of APTA document figures.

<table>
<thead>
<tr>
<th>Figure #</th>
<th>Comment</th>
<th>Comment</th>
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<tbody>
<tr>
<td>1</td>
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<td>2</td>
<td>Applies</td>
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<tr>
<td>3</td>
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<td></td>
</tr>
<tr>
<td>4</td>
<td>Applicable, except no &quot;C&quot; contacts required</td>
<td></td>
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<tr>
<td>5</td>
<td>Applies</td>
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<tr>
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<tr>
<td>7</td>
<td>Applies</td>
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<tr>
<td>8</td>
<td>Applicable, except for no F-End isolation switch or engine layover heater</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Not Applicable</td>
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<tr>
<td>10</td>
<td>Applies</td>
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<tr>
<td>11</td>
<td>Applies</td>
<td></td>
</tr>
</tbody>
</table>

APTA RP-E-015-99 Figures

Trains which receive HEP power from this locomotive conform to APTA RP-E-016-99, “Recommended Practice for 480VAC Head End Power System”, for a Single Bus system, described primarily in section 4.4. The table below indicates applicability of APTA document figures.
### 2.2.17 Door System

The locomotive shall have provision for interface with a passenger car door interlock system that shall inhibit propulsion power when exterior doors are open. Input from the train shall be a signal suitable for a relay coil operation.

### 2.2.18 Ride Quality

#### 2.2.18.1 General

Locomotive ride quality shall meet ISO 2631/1, 8-hour fatigue decreased proficiency boundary (FDPB) lateral, 8-hour FDPB vertical, and 8-hour FDPB longitudinal criteria at the authorized track speed on the normal high-speed trackage between Perryville, MD and Newark, NJ over track meeting the minimum FRA class for the speed.

Actual ride quality achieved shall be verified through qualification testing in accordance with the following method. For locomotives, there shall be one sensor centrally located in the operating cab. Ride quality acceptance shall be by comparison of whole-journey, weighted one third-octave band acceleration amplitudes from each sensor location with the relevant single lateral, vertical and longitudinal ride quality criteria, respectively. Results shall be reported for each of the three axes of each sensor, and all shall meet the specified ride-quality requirement. Data taken during station stops shall not be included.

The locomotive shall be designed and constructed so that lateral accelerations experienced by the crew do not exceed 0.5g peak-to-peak. Vertical accelerations experienced by the crew shall not exceed 0.9g peak-to-peak.
The locomotive shall be designed to provide smooth ramping between notch 0 and notch 1 to provide an acceptable level of the start of movement and ride quality.

Quasistatic lateral acceleration level in curves as measured by floor-mounted accelerometers shall not exceed 0.12g quasistatic at 5” cant deficiency

### 2.2.18.2 Ride Quality Analysis

The Contractor shall perform a three-dimensional dynamic simulation of the locomotive to show by analysis that the design meets the specified ride quality requirement. The dynamic simulator shall be selected by the Contractor based on its experience with similar analyses of high-speed rolling stock.

Track-geometry input data shall be actual vertical and lateral rail position data from the Northeast Corridor.

Prior to performing the analysis, the Contractor shall submit a description of the dynamic simulator for SEPTA approval. Included with the description shall be a list of the input data, the locations on the Northeast Corridor which shall be used for the track-geometry input data, a sketch showing a sample representative physical model, a list of possible output with samples of each, a list of previous projects where the proposed dynamic simulator was used, and a summary of the results of any calibrations of the proposed dynamic simulator.

The Contractor shall prepare a final report of the results of the dynamic simulation in accordance with this Section. The report shall include an update of the description, replacing the sample data and output with the actual data and results. Ride quality shall not exceed the boundary defined by the specified ride quality requirements, and car body excursions shall not exceed the clearance requirements specified in Section 2.2.3.3.

SEPTA approval of the final report shall be required prior to approval of the truck drawings.

### 2.3 NOISE AND VIBRATION

#### 2.3.1 Exterior Noise

The maximum exterior noise level (Lmax) produced by the locomotive at 135 mph shall be 90 dBA or less when complying with the provisions of 40 CFR 201 and 49 CFR 210. Noise testing shall be conducted at a mutually-agreed test site having suitable conditions regarding ballasted track, rail head conditions, adjacent land use, and similar features. The test site used for FEIS or equivalent shall be used as the test site. In addition, the following noise limits shall be met:

- **Standing, Blowers on**
  - Not to exceed 67 dBA at 100 ft

- **Standing, Blowers on 1000 KW HEP load nominal from side of locomotive with air compressor and Cab Air Cond., running**
  - No to exceed 80 dBA at 100 ft; Taken alongside the locomotive on a passenger platform
Standing, with power applied and blowers at station stop level, HEP/MPU, Air Comp., and Cab Air Cond., operating
Not to exceed 78 dBA at 100 ft; Taken alongside the locomotive on a passenger platform

Standing, Air horn blown full psi
Must be able to meet the requirements of 49 CFR 229.129.

Standing, Blowers on, Bell on
Bell clearly discernable at all measuring locations.
Bell not to be located beneath the cab floor, and to have noise isolation from the locomotive frame

Truck or body mounted shrouds may be provided as necessary for noise abatement at high operating speeds.

2.3.2 Interior Noise

Cab noise level shall be as specified in Section 5.9.

2.3.3 Interior Vibration

Under all normal conditions of operation, vibration of interior components, such as walls, ceiling panels, light fixtures, seats, and partitions, shall not be visibly or audibly perceptible. The following are maximum acceptable levels:

- Deflection of 0.10 in peak-to-peak for frequencies below 1.4 Hz,
- Acceleration of 0.01g peak for frequencies in the range of 1.4 Hz to 20 Hz, and
- Velocity of 0.03 in/s peak for frequencies above 20 Hz.

2.4 LOCOMOTIVE AND DIAGNOSTIC SYSTEMS

A system shall be provided to monitor performance of locomotive systems and subsystems on a continuous basis and to indicate the operating and functional status of all systems, including, propulsion and electric brake, auxiliary power, lighting, friction brake, on-board signal systems, and communications.

Monitoring screens shall be provided in each operating cab. Data displayed on the monitor screens shall be menu-driven and shall be based on a hierarchy of importance to safe operation. The monitoring system shall include instructions for fault handling and may, where necessary, limit locomotive operation.

All locomotive control systems shall be equipped with self-diagnostic capabilities and shall be in constant communication with the monitor through the locomotive diagnostic system. Self-diagnostic capabilities shall include all symptomatic sensors, devices, and methods necessary to determine when performance of the monitored system is deteriorating to the point where system failure is imminent.
When the locomotive systems do not have an inherent self-diagnostic capability contractor shall include a basic function within the locomotive diagnostics.

### 2.5 SAFETY

#### 2.5.1 System Safety Program

The Contractor shall develop, implement, and maintain a comprehensive System Safety Program (SSP) conforming to the guidelines and requirements of 49 CFR 238.105. SEPTA shall use the implementation guidelines of 49 CFR 238.105 as the basis for determining the acceptability of the Contractor's SSP.

The SSP shall identify all hazards related to the locomotives, and impose design requirements and management controls which prevent mishaps by eliminating hazards or reducing risks to levels acceptable to SEPTA. Locomotive system software shall be treated as a safety-critical item and shall be included in the development of the SSP to ensure reliable, fail-safe system software. The SSP shall be developed in the earliest phases of the Contract and shall be continuously maintained throughout as the design and construction evolves.

Safety requirements defined in this Section and elsewhere in this specification shall be incorporated into the SSP and the Contractor's designs.

#### 2.5.2 Applicability of 49 CFR 238.105

Specific portions of 49 CFR 238.105 are referenced herein. These references shall not be construed as limiting the applicability of any portions of 49 CFR 238.105. Requirements may be waived only where approved by SEPTA.

Formats for reports, listings, analyses, and other required documents shall be submitted for approval by SEPTA. All documents shall be submitted on approved forms. Where necessary, the Contractor's methods and analyses shall be amended to provide all the information required by the approved forms.

#### 2.5.3 General Design Requirements

Hazards shall be resolved according to the precedence rules listed in paragraph 49 CFR 238.105, with the restriction that hazards with a Category I and II, all levels of probabilities, and hazards of Category III with a level A probability (as defined in 49 CFR 238.105) shall be resolved only by the methods contained therein, unless approved by SEPTA.

The general safety design requirements of 49 CFR 238.105, and the guidelines listed below, shall be incorporated into the design of the locomotive systems affecting safety:

1. All items identified as SAFETY CRITICAL shall be automatically monitored for performance.

2. Only components with high reliability and which have been proven in conditions similar to the projected service shall be utilized.
3. All devices not guaranteed to be fail-safe shall be assumed capable of failing in permissive modes.

4. All electronic circuits shall be assumed to be capable of failing in permissive modes.

5. Software shall be considered unsafe unless verified in an approved program while operating in the proposed hardware.

6. Systems shall be based on closed circuit principles in which energized circuits result in permissive conditions, while interrupted or de-energized circuits result in restrictive conditions.

7. All vital circuits not wholly within the system apparatus enclosure shall be double-wire, with the exception of connections to non-vital circuits, which may be single-wire, single break.

8. Any component or wire becoming grounded shall not cause a permissive condition. Safety circuits shall be kept free of any combination of grounds that shall permit a flow of current equal to, or in excess of, 75 percent of the release value of any safety device in the circuit.

9. Circuit impedances, signal encoding, shielding, layout, and isolation shall be selected to minimize the effects of interference to the extent that safety is maintained under all conditions.

10. Commands that result in permissive conditions shall be propagated by no less than two independent signals, both of which must be present before the permissive condition can occur. The lack of either signal shall be interpreted as a restrictive command.

11. Systems controlled by variable level signals shall be arranged such that a zero level signal results in the most restrictive condition. At least one enabling signal, independent from the variable control signal, shall be present before the control signal can modulate the system to a more permissive level.

12. Circuit breakers, (which should be double pole, with positive/negative breaks) shall be guaranteed by the manufacturer to successfully interrupt rated currents. Circuit breakers and fuses shall be applied such that the maximum circuit fault currents cannot exceed the manufacturer's guaranteed operating ranges.

13. Systems that rely on structural integrity for safety shall have sufficient safety factors such that failures do not occur within the life of the vehicle under all foreseeable conditions.

14. Systems subject to wear shall not wear to permissive states within a period no less than three times the overhaul period under the worst-case combination of duty cycle, environment, and other influences. Such devices shall be clearly indicated as SAFETY CRITICAL in the maintenance manuals.

15. Mechanical systems which apply force to achieve safe states shall not depend upon the application of fluid pressure or electrical energy, unless specifically approved.

16. All locks, catches, and similar devices affecting safety shall be either self-engaging without the application of power, or, if engaged by the application of power, shall remain fully engaged in
the absence of power. They shall not be operable by use of common tools such as screwdrivers, pliers, etc.

17. All systems shall function safely under all combinations of supply voltages, fluid pressures, shock, vibration, dirt accumulation, and the SEPTA environment.

18. All safety-related systems, and devices within those systems, shall be clearly identified as SAFETY CRITICAL in all operation and maintenance manuals, procedures and training materials.

2.5.4 Failure Induced Hazards

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

Locomotive systems whose failure could result in hazards of Category I or II of all probability levels, or Category III hazard with a level A probability shall conform to both of the following design principles:

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

The term "failure" includes both the initial device failure and all consequential device failures cause by the initial failure.

The term "device" includes any component, subsystem, or system, whether electrical or mechanical.

The terms "restrictive" and "permissive" relate to potential system responses, which result in either a safer or less safe condition, respectively, such as: Stop versus Proceed, a lower speed versus a higher speed, deceleration versus acceleration, etc.

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

- The utilization of fail-safe devices, that is, devices with known, guaranteed-by-the-manufacturer failure modes, such as signal grade relays.
- Independent channels with independent checking of each. All channels shall indicate a permissive state in order that the controlled system achieves a permissive state. Failure in any channel shall not affect any other channel, or force the system to a permissive state. Lack of correspondence between channels shall be alarmed and shall force a restrictive state upon the system. Checking equipment invariably requires devices conforming to the previous method.

Failures in equipment which result in an indication of danger, whether or not actual danger exists, shall be considered to have occurred in a safe manner. Conversely, a failure which results in an indication of safety when a dangerous condition may exist shall not be considered safe.
2.5.5 Friction Brake System

An independent failure detection system shall compare the brake commands with the friction and electric brake outputs to determine if a failure has occurred, and indicate any failure to the locomotive monitoring system.

2.5.6 Fire and Life Safety

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

Design shall provide for equipment to be located outside of the cab, whenever practical, to isolate potential ignition sources from combustible materials. The floor shall be designed to prevent propagation of an underfloor fire to the locomotive. Fire-stops shall be provided at floor and roof penetrations. Enclosures for control and other critical equipment shall be located to provide protection against environmental contamination and mechanical damage.

2.5.7 Safety under Normal Operating Conditions

The locomotive shall present a safe, hazard-free environment to SEPTA personnel.

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

Normal and emergency equipment and controls which the personnel may operate shall be clearly identified and operating procedures shall be presented in both printed and graphic formats.

The Contractor shall provide Material Safety Data Sheets for all hazardous materials. The data sheets shall be provided during the design review phase of the project. The data sheets shall include all materials used to produce the locomotive as well as all materials provided with the locomotive.

Maintenance manuals, procedures, and training shall indicate the proper handling, storage and disposal of hazardous materials. Exposure of maintenance personnel to lethal or injurious voltages shall be minimized through compartments, interlocks, and similar measures. All equipment shall be free from sharp points and edges. All equipment containing hazardous materials, lethal or injurious voltages, or other risks shall be clearly labeled on both the outside and the inside of the equipment enclosure.

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

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

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

2.5.9 Hazard Identification

The Contractor shall identify all failure-induced and normal operating (non-failure condition) hazards falling into severity categories I, II and III. Hazards shall be compiled into lists and submitted for approval to SEPTA during the design review.

As required by MIL-STD-882C, the hazard lists shall be organized into Preliminary Hazard List, Subsystem Hazard List, and System Hazard List.

In addition to those hazards identified by the Contractor, the following hazards shall be included in the listings and shall be considered hazards of Category I or II severity:

1. Emergency brake fails to apply when requested.
2. Service brakes fail to apply when requested.
3. Propulsion fails to cease when requested.
4. An axle speed varies significantly from locomotive speed.
5. No-motion detection system indicates no-motion when the locomotive is moving.
6. Door open spontaneously when not commanded by crew.
7. Doors open spontaneously when not commanded.
8. Door interlocks erroneously indicate door is closed and locked.
9. Locomotive responds in a permissive manner to a restrictive Cab Signal Aspect.
10. Excessive currents or overheated equipment cause a fire hazard.
11. Locomotive moves in the wrong direction.
12. Locomotive speed and track curvature combine in such a manner as to cause a locomotive to derail or a vehicle to overturn.
2.5.10 Hazard Analyses

The Contractor shall perform hazard analyses on all hazards identified in the hazard lists developed above. Analyses shall demonstrate that the locomotive conforms to the requirements of this Specification and that all identified hazards are either eliminated, or reduced to levels of risk acceptable to SEPTA.

During the analysis process, the Contractor shall be responsible for the correction of those software hazards identified under Section 2.5.9.

All hazard analyses shall be adjusted or amended as locomotive design and construction progresses.

The analysis methods shall be selected by the Contractor as appropriate for the system under evaluation and the Category of hazard severity, subject to the approval of SEPTA. Hazards of Category I and II severity shall receive analyses sufficiently rigorous to demonstrate that the hazard cannot occur, or the associated risk is reduced to a level acceptable to SEPTA. The Contractor shall demonstrate by test the validity of portions of the analyses of Category I or II severity hazards.

Standard failure and safety hazard analysis methods, and published failure rates for components, shall be utilized wherever possible. All electrical circuit failure mode analyses shall include a sneak circuit analysis. All methods shall be submitted to SEPTA for review and approval.

Existing hazard analysis of like equipment operating under like conditions may be offered in lieu of performing a complete analysis of proposed equipment, subject to SEPTA approval. Analyses or tests required by other sections of this Specification, such as structural analyses or fire penetration tests, may also be submitted for consideration by SEPTA in response to this hazard analyses requirement.

Analyses shall identify all maintenance errors that could result in unsafe conditions, such as incorrect adjustment of sensors. Analyses shall also include design errors that could produce unsafe conditions, such as improper circuit breaker type or rating and temperature or environment dependent device selections.

2.5.11 Software Safety

The System Safety Program shall include a software safety section which applies to any embedded or external software or firmware which controls or monitors safety-critical functions. The requirements for software safety, which shall be in addition to the requirements of Section 15, shall meet or exceed the requirements of the SEPTA Software Safety Plan, in accordance with 49 CFR 238.105, and CENELEC Standard EN50128, Railway Applications: Software for Railway Control and Protection Systems, especially sections 8 through 17. In-process reviews shall be held for Engineer approval at the 50 percent, 80 percent and 100 percent completion points.

Software safety requirements shall treat software as an integral part of a hardware/software system. Functions accomplished through the use of software shall be considered safety critical unless an independent redundant hardware means is also provided to accomplish the same function.

Features of the software safety program shall include a description of how the following shall be accomplished: definition, implementation and oversight of the software design and verification process, integrity of the documentation, software hazard analysis, software safety reviews, software hazard
monitoring, reporting and tracking, and software integration with hardware at each stage of the design and testing process for components, subsystems, systems, cars, consists and trains incorporating software for safety-critical functions.

2.5.12 Locomotive Electronics Safety Requirements

The Contractor shall develop Safety Analyses (SA) per 49 CFR 229 Subpart E – Locomotive Electronics. These reports shall be submitted for review and approval by SEPTA, and the Contractor shall support SEPTA throughout the FRA review of the SA. The Contractor shall provide documentation, training, and support as required by the approved Safety Analysis, FRA, and 49 CFR 229 Subpart E, including:

- Product testing results and record
- Operations and maintenance manuals
- Training and qualification program
- Operating personnel training

2.6 Electromagnetic Compatibility

The Contractor shall develop an EMC Control Plan for review and approval by SEPTA. This plan shall include all design techniques, features, laboratory testing and field testing used by the Contractor to ensure EMC.

The Contractor shall develop an EMI Safety Analysis that evaluates and mitigates the hazards presented by EMI to all on board systems and all wayside systems. Special attention shall be given to cab signal system and wayside signaling systems.

Except as otherwise noted herein, the locomotive shall conform to EN50121-3-1, and all relevant components shall conform to EN50121-3-2.

2.6.1 General EMC Testing

This testing consists of two levels: 1) Laboratory Testing of each electronic sub-system on the locomotive as a standalone test to verify emissions and susceptibility. 2) Field Testing of complete locomotive to verify emissions and susceptibility.

The purpose of the laboratory testing is to qualify each subsystem before it is installed in the vehicle. This is done at an early stage to allow time for design modifications if required. The field testing is used to qualify the entire locomotive and ensure EMC with its operating environment.

2.6.2 Laboratory Testing of Each Subsystem

Each subsystem on the locomotive capable of producing or being susceptible to EMI shall be subjected to the following tests:

1. FCC Part 15.109 Radiated Emissions: This test shall cover 30 MHz to 6 GHz
2. FCC Part 15.107 Conducted Emissions: This test shall cover from 0.15 MHz to 30 MHz.
3. IEC 61000-4-2 Electro-Static Discharge (ESD): Performance Criteria B shall apply.

4. IEC 61000-4-3 Immunity to Radiated Fields: This test shall cover from 80 MHz to 6 GHZ. Test shall be done at 20 V/m and Performance Criteria A shall apply.

5. IEC 61000-4-4 Immunity to Electrical Fast Transients (EFT): Performance Criteria A shall apply.

6. IEC 61000-4-5 Immunity to Surges: Performance Criteria B shall apply.

7. IEC 61000-4-6 Immunity to Conducted RF: Performance Criteria A shall apply.

The Contractor shall generate detailed test procedures for each of the above tests and submit them for approval by SEPTA.

### 2.6.3 Field Tests of Locomotive

The locomotive shall be subjected to the following field tests to verify EMC with its environment. These tests must be performed at SEPTA and shall not be waived per Section 1.2.3.

#### 2.6.3.1 Radiated Emissions

The Contractor shall generate a detailed test procedure and submit it for review and approval by SEPTA. This test procedure should use APTA SS-E-010-98 as a guide line.

The following limits shall apply:

- 109 dBµV/m/MHz at 0.15 MHz, linear on log frequency plot to 85 dBµV/m/MHz at 30 MHz.
- 58 dBµV/m/MHz from 30 MHz to 90 MHz.
- 68 dBµV/m/MHz from 90 MHz to 6 GHz
- Measured at 50 feet from center line of rails.

#### 2.6.3.2 Conductive Emissions

The following limits shall apply: The curve in Amtrak drawing A-60-7659, Rev. B shall apply from 10 Hz to 500 Hz.

The Contractor shall generate a detailed test procedure and submit it for review and approval by SEPTA. This test procedure should use APTA SS-E-010-98 as a guide line.

#### 2.6.3.3 Inductive Emissions

The Contractor shall generate a detailed test procedure and submit it for review and approval by SEPTA. This test procedure should use APTA SS-E-010-98 as a guideline.
The following limits shall apply: 100 millivolts RMS from 0 to 500 Hz and 20 millivolts RMS from 500 Hz to 20 kHz.

2.6.3.4 Cab Signal Interference (CSI)

The Contractor shall generate a detailed test procedure and submit it for review and approval by SEPTA.

The following limits shall apply: The maximum CSI measured at the output of the track receiver coils shall be a minimum of 6 dB lower than the susceptibility level of the cab signal system as determined and verified by laboratory testing. In no cases shall it be higher than the following:

- 90 Hz thru 103 Hz 300 milliamps maximum;
- 245 Hz thru 255 Hz 150 milliamps maximum;
- Shall be a minimum of 6 dB lower than the susceptibility level of the cab signal system as determined and verified by on track testing with rail loop (axle) currents as follows:
  - 90 Hz thru 103 Hz 500 milliamps maximum
  - 245 Hz thru 255 Hz 250 milliamps maximum

2.6.3.5 Compliance to IEEE 519

The contractor shall perform testing to verify that the locomotive complies with IEEE 519 under all modes of operation including any permitted degraded modes.

2.6.3.6 Critical Frequency Zones

With respect to Amtrak drawing A-60-7659, Rev. B, please note the following:

- 90-103 Hz, 150-162 Hz, and 195-205 Hz not to exceed 0.6 A
- 245-255 Hz not to exceed 0.3 A.

These are very critical limits for the cab signal system and for track circuits in the signal system, and must be limited to the values shown.

In addition, the Third and Fifth Harmonics of the above, 300, 468, 500, 600, 750, 780, 1000 & 1250 Hz, must be avoided to ensure the above levels are not exceeded anywhere in the critical ranges specified above.

In addition, note the requirement for levels not to exceed 0.03 A (30 mA) in the range 500-7000 Hz. This requirement includes the not to exceed levels for the Third and Fifth Harmonics listed above, as well as a host of longer range audio track circuits with frequencies interspersed between the specific harmonics listed.
Finally, >7KHz (7000 Hz) there are shorter range overlay track circuits where levels must not exceed 0.004 A (4 mA).

### 2.6.3.7 Power Lab Testing of Propulsion System

The Propulsion system supplier shall perform Conducted Emissions testing of the Propulsion and HEP systems in the power lab to obtain a early measure of the conducted EMI.

The Contractor shall generate a detailed test procedure and submit it for review and approval by SEPTA. This test procedure should use APTA SS-E-010-98 as a guide line.

### 2.6.4 Test Procedures

All test procedures must be submitted for review and approval by SEPTA prior to any formal EMI testing.

All test procedures must contain as a minimum the following items:

1. Complete listing of all test equipment and instrumentation used in the testing.
2. Block diagrams, schematics to illustrate the interconnections between the unit under test to the test equipment and instrumentation.
3. A step-by-step instruction of the test set-up and conditions for each test.
4. Pass / Fail criteria

### 2.7 RELIABILITY

The Contractor shall prepare and maintain a Reliability Program Plan. The plan shall require that a reliability analysis be performed for each component, system and the complete locomotive type. The reliability analysis shall list each component generic type and base failure rate using handbook data or operating experience.

For an analysis using handbook data, the environment factor, and quality factor as defined in MIL-HDBK-217F Notice 1 or IITRI/RAC Document NPRD-91 shall be listed. All handbook reliability analysis shall be performed using the Ground Mobile environment mode and commercial quality factor parts, and the prediction shall be based upon the Parts Count Method described in MIL-HDBK-217F Notice 1. A quality factor of 10 is to be used for commercial reliability chosen from NPRD-91. If a higher-level quality factor part is preferred, the Contractor must demonstrate the current availability of this part from commercial sources.

The MDBF to be used in the analysis shall be equivalent to the reciprocal of the hazard rate which is used in the exponential probability of survival. The MDBF calculation shall assume constant failure hazard rate for systems and components, unless noted by the Contractor. If other than constant hazard rate is assumed for any component or system, supporting evidence shall be provided as to the reason for the variation (i.e. infant mortality, system development, etc.).
For analyses where operating experience is used instead of handbook data, the MDBF shall be the total locomotive miles in a one year period divided by the total failures in that same one year period.

The Reliability Program Plan and a Preliminary Reliability Analysis shall be submitted within 90 days from Notice-to-Proceed. The Reliability Analysis shall be updated during the vehicle design process to correspond to design changes that affect reliability.

A locomotive shall have a mean distance between failure (MDBF) rate of no less than 60,000 miles for failures which cause a train delay in excess of 15 minutes based on current SEPTA schedules, which nullify a train, or which cannot be corrected in the normal turnaround and maintenance times in Section 2.9. Train delays or nullifications due to excessive EMI detected by the EMI black box shall not be counted in these MDBF’s.

For failures which result in a train delay in excess of 15 minutes, the propulsion system shall have an MDBF of 300,000 miles, the auxiliary power system shall have an MDBF of 100,000 miles, and the compressed air supply and friction brake system shall have an MDBF of 60,000 miles.

The Contractor shall monitor the fleet operation for a period of two years after the last locomotive is accepted into service in order to verify that the reliability goals have been met.

### 2.8 MAINTAINABILITY

The locomotives shall be designed and constructed to meet specified maintenance requirements.

The use of modules, self-diagnostics, quick-disconnects, and similar devices shall be maximized to facilitate component exchange and off-vehicle repair of defective components.

Equipment layout and access points shall be coordinated to provide ready access for maintenance and inspection purposes.

The Contractor shall show during design reviews the layout and ease of maintainability of each item on the locomotive to ensure specification compliance. The areas of high failure probability (high stress voltages, current or mechanical devices, etc.) shall be designed to limit the failure damage to a confined area and not to effect other equipment or devices. SEPTA reserves the right to witness the installation and removal of equipment. Equipment accessibility review shall specifically be included in FAI (First Article Inspection). Access to major components and items such as the transformer shall be designed for ease of replacement.

The Contractor shall submit a Maintainability Program Plan, which defines the design efforts that shall be made to accomplish the manufacture of a locomotive with reduced maintenance time for major systems, subsystems, or critical components. The Maintainability Program Plan shall be submitted within 90 days from Notice-to-Proceed.
2.9 MAINTENANCE SCHEDULE REQUIREMENTS

The locomotive shall be capable of being maintained in accordance with the following maintenance schedule:

1. Turnaround: 30 minutes maximum service time to accommodate light cleaning, inspection, review of diagnostic system reports, and minor repairs between trips. The locomotive shall be designed to accommodate turnaround maintenance at station platforms at terminal points.

2. Layover: Three hour maximum service time to accommodate turnaround activities plus basic cleaning and repairs during off-service hours. Layover maintenance shall take place on a daily basis and shall be conducted at SEPTA shops and yards. Transit time between stations and repair facilities shall not be included in the three hour window available.

3. Defect Maintenance: Unscheduled repair work, the duration of which exceeds the time window available (i.e., one hour or three hours) for turnaround or layover maintenance.

4. 92 Day inspection Scheduled extraordinary cleaning and progressive maintenance, such as wheel truing. Cycle time shall be based on equipment utilization and locomotive maintenance requirements as defined by the Contractor, but shall be no more frequent than a 92-day inspection cycle. The time available for 92 day maintenance shall be 36 hours; Contractor may submit an alternative duration for consideration.

5. Annual: Scheduled heavy progressive maintenance and cleaning. The time available for annual maintenance shall be 48 hours; Contractor may submit an alternative duration for consideration.

6. Overhaul: Scheduled heavy rebuild or replacement of operating systems. Overhaul cycle shall be based on equipment utilization and shall be determined by the Contractor. Overhaul shall take place at a backshop facility at a site which may be in proximity to or distant from SEPTA operating territory. The Contractor shall define the frequency and duration of overhaul work, including transit time to the Contractor-determined overhaul site.

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10 TRUCK AND SUSPENSION

10.1 GENERAL

Each locomotive shall be equipped with two (2) four (4) wheel trucks with outboard roller journal bearings. The truck may have a cast or fabricated steel frame, and may include local steel castings as required. Overall truck weight and unsprung mass shall be held to a minimum without sacrificing required strength, good performance, and low maintenance. Trucks shall be suitable for continuous operation at service speeds up to 125 mph on Amtrak’s NEC track (equivalent to Class 7 track) with qualification testing at 135 mph, and shall provide a safe, comfortable, and stable ride per the requirements called for in Section 2.2.16. The trucks may be semi selfsteering. Only trucks manufactured by an experienced supplier who has confirmable previous satisfactory experience in railway passenger truck design and manufacture on North American commuter railroad passenger systems shall be accepted. Trucks and components shall be only of a service proven design, meaning a design which has operated in regular revenue service at speeds up to at least 125 mph. The Contractor shall submit the design details and service history of the truck noting any deviation for this application to SEPTA for review and approval, prior to truck selection.

The trucks shall be designed to accommodate brake equipment as required by Section 11 and sanding equipment as required by Sections 3.8 and 5.13. Tread brakes, shall be limited to providing less than fifteen percent (15%) of the friction brake capacity, or the level which produces a tread surface temperature of 600 °F under worst-case conditions, whichever is less. The brackets shall be designed so that components from a minimum of two (2) suppliers can be applied. The mounting provision shall be able to withstand all forces of a tread brake unit without wear to the truck-mounted equipment and shall be designed for overhaul on the same cycle as the truck itself. Trucks shall be designed with brackets and mounting provisions as necessary for the appropriate sensors and signal antennas.

Ease of maintenance is of high importance. Accordingly, the truck will be designed to allow quick removal of the wheel set, gearbox and traction motor individually or as a unit, from the locomotive, with the use of a drop table. The truck shall provide unobstructed access to all parts which require periodic inspection, lubrication, removal, and/or replacement without requiring removal of any other apparatus. Items that require routine maintenance shall be attached with bolts. It is preferred that the truck shall allow complete disassembly of all components when positioned on the shop floor without the aid of a truck stand. The need for special tools and equipment shall be minimized. Inspection covers, when removed, shall provide clear visibility to all apparatus that requires inspection and/or maintenance. The assembled truck and its components shall ensure maintenance personnel safety during shop activities. Sharp edges and pinch points are to be eliminated whenever possible. Pockets or partially enclosed spaces where standing water can collect should be avoided but when not possible, adequate drainage shall be provided. All pockets and spaces shall be arranged such that debris, leaves, trash, etc., cannot accumulate. Truck serial numbers shall be applied to both sides of each truck in a readily accessible area.

The complete truck and each of the truck components shall be interchangeable between ends of each locomotive and between locomotives. Trucks shall be capable of operation in either orientation (between F & R end) positions in the locomotives, without modification except relocation of signal
antennas. All air brake piping on the truck and from the carbody to truck shall be installed in a protected environment. Air piping shall not be routed beneath the truck. Access to all piping and hoses for inspection or replacement shall not require more than five (5) minutes. Clamps for piping, cables, etc shall be attached to tapping plates or raised bosses.

Each truck frame shall be equipped with a riveted-in-place metal identification plate with serial number. The serial number shall also be available as a permanent, indelible bar code.

Truck mounted components and equipment shall be capable of withstanding without damage or degradation shock and vibration requirements of IEC 61373, 1999, as a minimum. In addition axle mounted components must be designed to withstand the shock and vibration environment of the northeast corridor, under winter (frozen ballast and sub grade) and summer conditions. Shock susceptible components shall be suitably shock mounted. In addition, truck components directly carried on the axles shall withstand continuous vibrations of at least 50 g’s up to 100 Hertz in all directions, as well as randomly oriented shock loads of up to 100 g’s.

10.1.1 Shock Loading Requirements for Axle mounted components

Shock susceptible components shall be suitably shock mounted to function in the SEPTA environment with maintenance standards congruent with acceptable periodic frequency for the assembly involved.

In addition to the requirements contained herein, the car shall meet the appropriate provisions for dynamic performance and simulations contained in 49 CFR 213.

10.2 CLEARANCES

The completely assembled trucks, with brakes and other equipment, shall not exceed the clearance limits required between truck and car body (one and one-half inches) or between truck and roadway for safe operation, with maximum wear and load, any one defective suspension component, over limiting lateral and vertical curves, as well as tangent track. Trucks shall be so designed that the maximum truck and car body vertical, lateral, and roll deflections with any one defective suspension component are within limits specified in the Construction Limit Outline and Clearance Diagrams, . All truck parts shall negotiate the minimum radius curve as specified in Section 2.2.10.3. The method of meeting these requirements shall be submitted to SEPTA for approval before the truck design is finalized.

Under emergency conditions, including restricted headroom, it shall be possible to remove a complete truck by detaching it from the car body by raising only the affected end of the locomotive. The car body shall only need to be raised sufficiently to permit the truck frame, bolster, and traction motors to pass beneath the coupler and coupler carrier. Any truck or car body mounted parts requiring removal to permit truck removal in this manner shall be attached with bolts, pins or other approved fasteners that are disassembled with basic tools.

10.2.1 Safety Criteria

Locomotive shall meet the safety criteria identified in 49 CFR 213.
The locomotive shall be tested in accordance with Section 16.7.3 using the instrumented wheel sets specified in Section 10.16. for:

### Vehicle/Track Interaction Safety Limits

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Safety Limit</th>
<th>Filter/Window</th>
<th>Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single Wheel Vertical Load Ratio</td>
<td>≥ 0.15</td>
<td>5 ft</td>
<td>No wheel of the vehicle shall be permitted to unload to less than 15 percent of the static vertical wheel load for 5 or more continuous feet. The static vertical wheel load is defined as the load that the wheel would carry when stationary on level track.</td>
</tr>
<tr>
<td>Single Wheel L/V Ratio</td>
<td>( \leq \frac{\tan(\delta) - 0.5}{1 + 0.5\tan(\delta)} )</td>
<td>5 ft</td>
<td>The ratio of the lateral force that any wheel exerts on an individual rail to the vertical force exerted by the same wheel on the rail shall not be greater than the safety limit calculated for the wheel’s flange angle (( \delta )) for 5 or more continuous feet.</td>
</tr>
<tr>
<td>Net Axle Lateral L/V Ratio</td>
<td>( \leq 0.4 + \frac{5.0}{V_a} )</td>
<td>5 ft</td>
<td>The net axle lateral force, in kips, exerted by any axle on the track shall not exceed a total of 5 kips plus 40 percent of the static vertical load that the axle exerts on the track for 5 or more continuous feet. ( V_a = ) static vertical axle load (kips)</td>
</tr>
<tr>
<td>Truck Side L/V Ratio</td>
<td>≤ 0.6</td>
<td>5 ft</td>
<td>The ratio of the lateral forces that the wheels on one side of any truck exert on an individual rail to the vertical forces exerted by the same wheels on that rail shall not be greater than 0.6 for 5 or more continuous feet.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Passenger Cars</th>
<th>Other Vehicles</th>
<th>Requirements</th>
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</thead>
</table>
| Carbody Lateral (Transient)      | \( \leq 0.65g \) peak-to-peak 1 sec window \( ^1 \) excludes peaks < 50 msec | \( \leq 0.75g \) peak-to-peak 1 sec window \( ^3 \) excludes peaks < 50 msec | The peak-to-peak accelerations, measured as the algebraic difference between the two extreme values of measured acceleration in any 1-second time period, excluding any peak lasting less than 50 milliseconds, shall not
### Southeastern Pennsylvania Transportation Authority

#### Section 10

**High Speed Locomotive Technical Specification**

**Trucks**

<table>
<thead>
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<th>Parameter</th>
<th>Safety Limit</th>
<th>Filter/Window</th>
<th>Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbody Lateral (Sustained Oscillatory)</td>
<td>≤ 0.10g RMS₆⁴ 4 sec window ¹ 4 sec sustained</td>
<td>≤ 0.12g RMS₆⁵ 4 sec window ² 4 sec sustained</td>
<td>Sustained oscillatory lateral acceleration of the carbody shall not exceed the prescribed (root mean squared) safety limits of 0.10g and 0.12g for passenger cars and other vehicles, respectively. Root mean squared values shall be determined over a sliding 4-second window with linear trend removed and shall be sustained for more than 4 seconds.</td>
</tr>
<tr>
<td>Carbody Vertical (Transient)</td>
<td>≤ 1.0g peak-to-peak 1 sec window ³ excludes peaks &lt; 50 msec</td>
<td>≤ 1.25g peak-to-peak 1 sec window ³ excludes peaks &lt; 50 msec</td>
<td>The peak-to-peak accelerations, measured as the algebraic difference between the two extreme values of measured acceleration in any one second time period, excluding any peak lasting less than 50 milliseconds, shall not exceed 1.0g, or 1.25g, as specified.</td>
</tr>
<tr>
<td>Carbody Vertical (Sustained Oscillatory)</td>
<td>≤ 0.25g RMS₆⁴ 4 sec window ³ 4 sec sustained</td>
<td>≤ 0.25g RMS₆⁴ 4 sec window ³ 4 sec sustained</td>
<td>Sustained oscillatory vertical acceleration of the carbody shall not exceed the prescribed (root mean squared) safety limit of 0.25g. Root mean squared values shall be determined over a sliding 4-second window with linear trend removed and shall be sustained for more than 4 seconds.</td>
</tr>
</tbody>
</table>

#### Truck Lateral Acceleration ₪

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Safety Limit</th>
<th>Filter/Window</th>
<th>Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Truck Lateral</td>
<td>≤ 0.30g RMS₆⁴</td>
<td>2 sec window ³ 2 sec sustained</td>
<td>Truck hunting shall not develop below the maximum authorized speed. Truck hunting is defined as a sustained cyclic oscillation of the truck evidenced by lateral accelerations exceeding 0.3g root mean squared for more than 2 seconds. Root mean squared values shall be determined over a sliding 2-second window with linear trend removed.</td>
</tr>
</tbody>
</table>

¹ The lateral and vertical wheel forces shall be measured and processed through a low pass filter (LPF) with a minimum cut-off frequency of 25 Hz. The sample rate for wheel force data shall be at least 250 samples per second.

² Carbody accelerations in the vertical and lateral directions shall be measured by accelerometers oriented and located in accordance with § 213.333(k).

³ Acceleration measurements shall be processed through an LPF with a minimum cut-off frequency of 10 Hz. The sample rate for acceleration data shall be at least 100 samples per second.

⁴ RMS₆ = RMS with linear trend removed.

₅ Truck lateral acceleration shall be measured on the truck frame by accelerometers oriented and located in accordance with § 213.333(k).
10.3 VEHICLE DYNAMICS

10.3.1 Ride Quality

Trucks shall be suitable for continuous service operation at all speeds up to 125 mph with qualification testing performed up to 135 mph and shall provide a comfortable ride at all speeds compliant with the ride quality and maximum safe operating speed test requirements of Section 2.16. The locomotive shall meet the requirements of 49 CFR 213.345 and 49 CFR 238.227. Cyclic truck or car body motion must be controlled to ensure safe operation, and occupant safety. A mathematical dynamic model of the locomotive shall be developed and submitted to SEPTA prior to any testing to predict the dynamic performance and ride quality. Along with all parametric inputs used in the simulations, including, but not limited to, all masses, inertias, damping characteristics, spring rates and critical dimensions which are input to the model along with an indication of the source of the data (ie.- manufacturer specs, contractor specs, analysis and/or measured data). The contractor shall also provide evidence of the comparison of past simulation and test data from the vehicle upon which the service record for this design is based along with any other data which is relevant to this model is a reasonably accurate simulation of the proposed vehicle. This model shall serve in part as the basis for any decisions for correcting dynamic performance and ride quality deficiencies. The model shall be developed on an industry accepted program such as Vampire, NUCARS or other generally accepted vehicle dynamic program.

Should the locomotives fail to satisfy the above mentioned requirements, a program for correcting the deficiencies shall be submitted to SEPTA for approval within ten (10) working days, together with a proposed schedule for completing the suggested correction. If, in the opinion of SEPTA, the program and/or schedule are inadequate or shall increase maintenance costs or otherwise adversely affect the serviceability, an acceptable program and schedule shall be resubmitted within five (5) working days. If the revised program and schedule are not submitted in time or are still unacceptable to SEPTA, SEPTA shall have the right to return the locomotives to the Contractor's plant at the Contractor's expense.

Should the locomotives, after correction, still fail to produce the riding qualities specified, SEPTA shall have the right to require the Contractor to make further modifications to bring performance to the required standards.

10.3.2 Track Forces

In addition to a minimum truck weight, the locomotive suspension shall be designed to minimize unsprung weight along with proper equalization.

To reduce unsprung weight, traction motors shall be fully suspended, mounted above the primary suspension. Gear box design and installation should minimize the amount of unsprung mass below the primary suspension or use a resilient mount connected to the wheel set. Locomotives shall be equipped with brake discs.
10.3.3 Curving
Trucks shall be capable of safe, stable operation at any speed up to maximum test speed specified in Section 2.2.7.1, while operating on track meeting only the minimum requirements of the FRA track safety standards for the speed operated.

10.3.4 Equalization
Truck equalization capability shall be sufficient to meet the requirements of APTA SS-M-014-06 for Class G equipment and be tested according to Section 5 of APTA SS-M-014-06. The vehicle shall safely negotiate all classes of FRA track, at the speed specified for that class of track.

The Contractor shall submit an Equalization Design Report.

10.4 SUSPENSION

10.4.1 General
The primary suspension shall be suitable for the operating service and performance levels specified herein. The secondary suspension coil springs shall have a 40% working-height reserve when subjected to the normal working load, and primary suspension coil springs, if used, shall have a 50% working height reserve when subjected to the normal working load. Pedestal tie bars, if used, shall be attached to the truck frame with a positive metal in bearing path for loads. The truck design shall cause the car body to rest on the secondary suspension at the extreme ends of the truck bolsters, if used, which, in turn shall rest on the truck frame either directly or via pendulum links. The truck design shall provide sufficient restraint to prevent “hunting” or nosing” of the truck at all speeds and at the same time allowing the locomotive to negotiate curves specified in Section 2.2.10.3 without causing excessive flange or rail wear. Sufficient elastomeric elements, including those above and below the springs shall be provided in the design to prevent direct structural borne noise being transmitted from the wheel set to the truck and from the truck to the car body. All components unless otherwise noted are expected to have a minimum eight and one-half (8-1/2) year life in the anticipated service specified in Section 2.2.

10.4.2 Center and Side Bearings
Center and side bearings, when used, shall be designed to permit rotation of the truck and to transmit vertical loads from the bolster to the truck frame. Load-carrying bearings shall be designed to dampen truck swiveling and prevent truck nosing and hunting. Effective sound damping shall be achieved and measured per Section 5.9. Wear limit grooves shall be inscribed in the material, and all bearing material shall have a minimum life of ten (10) years. The Contractor shall submit designs and data for all bearings to SEPTA for review and approval.

10.4.3 Stops
Lateral and vertical stops shall be designed with a progressive rate to produce a low force at initial contact which shall build up as the stop is compressed. Stops shall develop sufficient force to limit motion but shall not be compressed solid under any conditions that can be developed in the truck
during normal operation. Solid mechanical stops shall prevent lateral and vertical displacement in excess of the allowable motion stipulated on the Construction Limit Outline. The Contractor shall submit designs and data of all stops to SEPTA for review and approval.

10.4.4 Wearing Parts

All wearing parts of the truck shall be provided with renewable liners of manganese steel, Teflon, or other materials as approved by SEPTA.

10.4.5 Dampers

Hydraulic dampers shall be installed between each end of the truck frame or bolster and the car body to provide vertical and lateral damping and to insure that specified ride quality is attained. The design life for all hydraulic dampers shall be no less than six (6) years. The lateral dampers shall not prevent the car body from centering on the truck after a lateral movement. Mountings for the dampers shall be sufficiently resilient to provide sound and vibration isolation between the truck and the car body.

The trucks shall be provided with yaw damper attachment points to accept approved dampers to control yawing motion. The truck shall be equipped with yaw dampers, if analysis, tests, or operation indicates that yaw dampers are required. As a minimum, yaw dampers shall comply with AAR “Performance Specification for Yaw-Damping Devices, found in MSRP Section C, Volume II, Part 1.

10.4.6 Truck Primary Suspension Tests

A load deflection test shall be performed to demonstrate that the spring rates of the suspension system in all axes are within the design limits of the locomotive. This test shall demonstrate that the suspension system responds as predicted and shall not result in excessive deflection or decrease truck clearance above top of rail to less than the minimum prescribed in Section 2.2.2. In addition, a test of equalization that demonstrates that the suspension system meets the requirements of APTA SS-M-014-06 for Class G equipment.

10.5 SAFETY BRACKETS AND LUGS

Brackets or straps shall be provided on the truck frames to engage safety lugs on major components including the propulsion motors, gear boxes and traction rods in the event of failure of the primary support arrangement. Stress in the safety components shall not exceed ⅔ of yield when engaged, and shall not exceed 3/4 of yield due to the impact caused by the equipment load being transferred from the failed primary support to the safety support components.
10.6 JOURNAL BEARINGS

10.6.1 General
Journal bearings shall be Timken, fully enclosed NFL (No Field Lubrication) roller bearings, with the truck frame appropriately marked. Journal size shall be in accordance with AAR requirements for vehicles operating at speeds in excess of 85 mph, and shall be not less than Type GG. Each journal bearing housing shall include provisions for both smoke and odor thermal warning devices, and temperature sensors. These devices shall be easily accessible for inspection and replacement. Locomotives shall be delivered with such warning devices installed. If smoke devices are not available, two (2) odor devices shall be supplied per journal bearing housing.

Under normal operating conditions, bearings shall not require inspection more than once every 500,000 miles. Journal bearings shall be designed for an ANSI/AFBMA L10 of 1,000,000 miles of service. The bearing type shall have had previous successful service application in railway locomotive use.

10.6.2 Journal Box Numbers
Journal boxes shall be numbered per AAR MSRP RP-514. Numbers shall be steel stamped on stainless steel plates riveted with stainless steel rivets at the same location on all truck frames. The stainless steel plates shall be interchangeable among all trucks.

10.6.3 Lubrication
Journal roller bearings shall be NFL ("No Field Lubrication") type completely lubricated when assembled by the bearing manufacturer. Journal bearing seals shall be rubbing type.

10.7 WHEELS AND WHEEL WEAR

10.7.1 Design
Wheels shall be manufactured according to AAR MSRP M-107/M-208, with a 1/40 tapered tread. Wheel profile shall be per APTA SS-M-015-06, Figure B.8, APTA 340 Wheel Profile. Wheels shall be machined all over removing mill scale and decarburized material from the plates to specified dimensions and tolerances. The wheel may have provisions for attaching disc brake friction surfaces to the plates as determined by the locomotive design. The back face of rim and hub and the tread shall be machined with the same set-up. Front and back faces of the rim shall be parallel within 0.005 inch total indicator runout (TIR). Each wheel shall be dynamically balanced by machining hub fillets, rim fillets, or plates with a maximum dynamic imbalance not to exceed 36 inch-ounces. All wheel set components shall be statically balanced and mounted such that the assembly does not exceed a static limit of 115 ounce inches.

Each wheel shall be inspected and tested per AAR MSRP M-107/M-208 Section 18.4, Ultrasonic inspection for the rim, and Section 18.5, Magnetic Particle Inspection for the plate. Wheels shall be certified before application to an axle. When assembling the wheels and axles, the wheel pairs shall be...
matched with respect to tape size in accordance with AAR Standards. All wheels shall be of a proven
design with the lowest possible mechanical and thermal stresses available. Finite element analysis of the
wheel design based upon AAR MSRP S-660 shall be submitted to SEPTA for review and approval.
Additional load cases shall be analyzed, where applicable, utilizing the typical brake route profile,
assuming dynamic brake failure to determine the maximum temperature and stress in the wheel plate
in combination with the mechanical loads of AAR MSRP S-660.

10.7.2 Material

Wheels shall be of wrought steel manufactured to APTA SS-M-012-99, Rev 1, Class B with a fracture
toughness (Kic) of 57 ksi square root inch minimum for any single sample and 62 ksi square root inch
minimum lot average. Fracture toughness testing shall be performed on each heat lot number, and each
test shall be performed in strict accordance with the procedures set forth in ASTM E 399, latest revision,
or an approved notch test.

10.7.3 Certification

Each wheel provided for this application shall have the following data submitted to SEPTA for review
and approval prior to mounting on axles: Serial Number; Brinell Hardness Test Data; Fracture Toughness
Test Data; Ultrasound Test Certification; and Ladle Analysis. This information shall be included in the
Locomotive History Book.

10.7.4 Wheel Wear Adjustment

The wheel design shall allow for, and provision shall be made for a minimum of 1-1/2 inches adjustment,
in at least three (3) equal steps of the truck height to compensate for wheel wear, equating to three (3)
inches reduction in wheel diameter. The design and method of height adjustment shall allow for quick
and easy adjustment without disassembly of truck or removal of the truck from the car body and shall
be approved by SEPTA.

10.7.5 Wheel Truing

Provision shall be made for the use of SEPTA’s wheel truing machines to turn wheels. Axle centers shall
be accessible without requiring disassembly of the truck or removal from the car body. A suitable tie
down point shall be provided to secure the wheel set to the truing machine.

Bearing end cap plugs, journal box dust covers, or ground brush devices may be removed for wheel
truing. The truck shall be fully compatible with SEPTA wheel truing machines including the currently
used centers. If compatibility is not possible, all required additional equipment (e.g. centers) or
modifications to the machine shall be at the expense of the Contractor. No part of the truck assembly or
car body shall interfere with or foul any part of the wheel truing apparatus. If further clarification on
wheel truing machine dimensions is required to meet these requirements SEPTA shall, upon request,
provide access to the machine for the Contractor’s inspection.
10.8 AXLES

10.8.1 General

Axles shall be solid and of forged carbon steel furnished to AAR MSPR M-101, Grade "F", quenched and tempered or Grade “H” normalized, quenched and tempered. The Contractor shall ensure the maximum fatigue resistance of all axle grooves and machine surfaces through the use of acceptable design and analysis, and cold rolling of grooves. The Contractor’s manufacturing process and quality assurance plan shall incorporate sufficient controls, inspections, and tests to ensure the axle provides the fatigue resistance required by the design. In all cases, the design of any grooves or other machined surfaces shall be subject to review and approval by SEPTA. Axles may be designed either using AAR methods, or EN13104, Powered Axle Design Method. The AAR fatigue allowables for axle material shall be used (AAR Report MR-390, Table 1). Higher fatigue values shall be considered if supported by fatigue tests of the actual material or a minimum 15 year service life of other axles in North American high speed service using the same analysis method and stress limits.

All axles shall be thoroughly inspected by the Contractor. Each axle shall be marked by the manufacturer in accordance with ARR Specification M-101 where applicable. The Locomotive History Book shall contain all inspection documents for the axles on that vehicle. A list of these documents shall be proposed to SEPTA for review and approval prior to shipment of the first locomotive. As a minimum, these documents shall include all inspection forms (visual, ultrasonic, magnetic particle, etc.), serial numbers, heat lot numbers, and other appropriate forms.

10.8.2 Mounting

All wheel set assembly work shall be performed in an AAR certified facility following AAR practices. A copy of the AAR certification shall be submitted to SEPTA for review during the design review and shall be subject to verification at any time. Any change in the facility’s AAR certified status during the course of wheel set production, shall be immediately brought to the attention of SEPTA.

Mounted wheels shall be concentric between bearing seat diameters and tread at the plane of the taping line within 0.005 inch total indicated runout (TIR) and shall not exceed 0.015 inch out of parallel to each other or to a plane perpendicular to the center line of the axle. The inner face of the wheel hub shall be perpendicular to the center line of the finished wheel bore within 0.002 inch TIR.

Pressure graphs and inspection sheets of mounting wheels, disc hubs, and journal bearings shall be supplied to SEPTA prior to installation for all wheel and axle assemblies. The hub and bore diameters of all fits shall be recorded and included on the inspection sheets and provided with all other pertinent information, as required by SEPTA, as part of the Locomotive History Book.

The wheels, brake discs, gears, and roller bearings shall be mounted using pressures and fits specified in the AAR Wheel and Axle Manual with the following exceptions. More restrictive conditions shall apply if recommended by the truck manufacturer.

1. Back to back wheel dimension shall be 53 3/8 inches, +0, -1/8 inch.
2. The bearing interference fit parameters shall be approved by SEPTA. At a minimum, each bearing cone diameter and the corresponding diameters of the bearing seats shall be measured at three (3) locations on their length and at 120 degrees on the diameter, and the interference fit shall be within limits at all measured locations. For each cone, nine (9) measurements are to be recorded, three (3) each at 3/8 inch inside from each face and at the mid-point. For seats, eighteen (18) measurements are to be recorded; their locations shall correspond to the locations for the cone measurements when seated. Alternatively, a snap gauge may be used to find the absolute minimum and maximum diameter for each seat and these values shall be recorded. This shall be strictly monitored and enforced; there shall be 100% surveillance of the entire bearing assembly process, including mounting.

3. The pressure “spike” parameters for mounting the bearings shall be approved by SEPTA. Specific mounting recommendations of the bearing manufacturer shall be provided.

Wheel sets shall be assembled to minimize static imbalance. The maximum allowable static imbalance is limited to 83 ounce inches. All wheel set components shall be individually balanced with the magnitude and location of the imbalance recorded. The components shall be selectively mounted to obtain the required static balance.

10.9 TRACTION RODS

Two (2) traction rods shall be provided on each truck, connecting the car body to the truck bolster if used. The rods shall extend horizontally from brackets attached to the side sills to brackets attached to the ends of the truck bolster and prevent longitudinal and swiveling motion between the car body and bolster. If bolsters are not used traction rods shall connect the truck frame to the car body along the vehicle center line. Elastomeric pads shall be installed between the traction rod assembly and brackets to permit vertical movement. Traction rods shall be designed and located to minimize inter-axle weight transfer and eliminate longitudinal vibration from the car body. The design and location shall be approved by SEPTA.

The traction rod arrangement for each truck shall, as a minimum, withstand a longitudinal load equal to four (4) times the weight of the complete truck, including motors, gear units, brakes, and other apparatus mounted thereon, without exceeding the yield strength of the materials used. Each of the brackets attaching the traction rods to the truck and car body, and the members to which these brackets are attached shall, as a minimum, withstand a longitudinal load equal to 1.5 times the associated calculated traction rod capacity without exceeding the yield strength of the material used.

Alternative arrangements shall be permitted. Any such alternative shall be discussed in detail at the time of design review. Equivalency for functionality of the traction rods and other requirements for carbody to truck attachment strength shall be required as prescribed in the specification.

10.10 DRIVE TRAINS AND GEAR BOXES

The traction motor, gear boxes and other drive train components shall be mounted in accordance with TS 11.3.2 to reduce unsprung weight. The traction motor gear cases shall be sealed and oil lubricated to extend lubrication maintenance periods in accordance with the latest practices for long life lubrication applications. A sight level indicator or dipstick shall be provided. The traction motors shall be designed
to operate one million miles between overhaul. The traction motor shall be guaranteed in the warranty to meet the one million mile period between overhauls. Intermediate maintenance, such as lubrication of the rotor bearings shall be designed to coincide with the wheel replacement intervals of TS 11.7.1.

The traction motor and gear unit shall be manufactured to withstand and survive impact from debris items such as tie plates at operating speeds up to 135 mph without damage. Full diagnostics and defect location, is required.

10.11 ELECTRICAL GROUNDING AND INSULATION

No current shall be returned to the running rail through journal bearings. This shall include both normal current and overload current due to insulation failures in locomotive equipment. The journal bearings shall be insulated from the truck frame. Seven (7) ground brush assemblies shall be provide, one for each of seven of the eight journal bearings. The eighth location is for cab signal use. A ground strap shall be installed between the car body and ground brush assemblies mounted to one journal bearing housing per axle (four (4) ground brush assemblies). The second ground brush assembly on three (3) axles shall be connected to the truck frame, which in turn shall be connected to the truck bolster, and the car body. Each ground brush assembly shall be equipped with a minimum of two (2) insulated brush holders. The assembly housing shall allow removal without dismounting any wheels or bearings. A constant pressure spring assembly shall hold each ground brush in uniform contact with the ground plate from a new to fully worn brush configuration. The brushes shall be easily removable from the holders without disassembling or removal of the brush holders from the housing.

Each assembly shall be capable of a continuous rating and peak current capability consistent with the normal operating current and peak fault current for this locomotive. The supplier shall calculate expected normal and fault currents for the locomotive and provide these calculations for review and approval.

Ground return connections shall meet APTA SS-E-005-98 requirements. Ground returns shall be provided to specifically designated ground pads. The design and ratings for the ground brush assembly and a block diagram of the grounding system shall be submitted to SEPTA during the design review of the car.

10.12 TRUCK STRUCTURE AND STRESS ANALYSIS

10.12.1 General

The truck frame and all truck parts, including foundation brake gear, shall be capable of withstanding the maximum stresses imposed by the forces acting on the frame, including track shocks, motor torque (including short circuit torque), air actuated tread and/or disc brakes and any possible combination of these forces. The Contractor shall submit a stress analysis plan and a stress analysis of the truck structure using the methodology and details as described below prior to commencing manufacture of truck parts. Trucks that have a proven service history without structural defects in North American may submit a previous stress analysis. Trucks designed and tested to an internationally recognized standard, such as UIC 615-4, shall be considered by SEPTA. In either case, the stress analysis, including pertinent
design details must be submitted to SEPTA for approval. The acceptability of the alternate documents shall be the decision of SEPTA. In lieu of the alternate qualification paths noted above, as a minimum the stress from the following loads including TS 11.15.2, TS 11.15.3 and TS 11.15.4, axle design loads of TS 11.8.1, traction rod loads of TS 11.9 and safety bracket loads of TS 11.5 shall be analyzed using finite element analysis (FEA) and manual calculations where appropriate and associated tests shall be performed as indicated.

Unless otherwise specified, maximum stresses at any location, from the analyzed loads shall not exceed 55% of the yield strength for the base material, or for welds the allowable stresses in AWS D1.1, 2006, Section 2, Part B. For the overload test loads, TS 11.15.3, the yield strength of the material shall not be exceeded. For the fatigue test loads, TS 11.15.4, the base material stress is limited to the smallest of 100% of the appropriate endurance limit when plotted on the modified Goodman diagram for the material, or the FTH value in Table 2.4 of AWS D1.1:2006. If stresses exceed the specified limits in any load case, the design shall be corrected to bring the test stresses within the allowable limits, the truck shall be reanalyzed and retested, and all trucks supplied under this Contract shall be corrected in accordance with the modified design.

The truck frame and all components shall be retained to the truck bolster, if used, and to the car body in accordance with 49 CFR 238.219 and APTA SS-C&S-034-99, Rev 2, Section 5.6. The 250,000 lb load of APTA SS-C&S-034-99, Rev 2, Section 5.6.2 may be transmitted from the truck frame through structural members, positive stops, or other rigid, mechanical safety devices, and/or combinations thereof to the car body bolster. Bolster traction rods shall not be used to provide any part of this strength. The car body bolster shall be designed to resist this load without damage. The lifting hooks and/or other members used to attach the truck to the car body shall be designed and located in a manner that shall minimize the possibility of damage during low speed derailments.

### 10.12.2 Stress Analysis Plan

The load cases to be analyzed shall be described and submitted in a Stress Analysis and Test Plan document. The plan shall present all load cases that shall be analyzed with linear finite element analysis, manual calculation and or test, and show the material properties, load being applied with the load application points, boundary conditions, and expected reactions. The plan shall also include a description of the major assumptions, and how the analysis results shall be correlated with the test results.

### 10.12.3 Finite Element Model

The finite element model shall be developed using an industry accepted program such as NASTRAN, ANSYS, or approved equal. Finite element models shall be submitted for review and approval on CD-ROM, DVD, or other approved media prior to submittal of analysis results. The preliminary and final model submittals shall be in paper form, and all model information contained in the report shall also be submitted in electronic form. The model shall be in a format that can be read by the translating program FEMAP or equal. For NASTRAN, this corresponds to the bulk data file with filename extension “*.NAS”; for ANSYS the command files with filename extensions “*.CDB” and “*.DB”. For other approved FEA codes, the Contractor shall contact SEPTA for the required files.
The element mesh, details of element selection, modeling assumptions, applied loads, boundary conditions, material properties, geometry properties, and all other inputs to the FEA shall be included as part of the model submittal, along with the drawings and supporting information used in developing the models. Element geometry properties shall be referenced to a drawing number or other source to facilitate verification. Solid elements shall be used to the extent necessary to ensure that the actual truck geometry is accurately modeled. The model shall contain sufficient detail to adequately model all of the significant structural elements and any highly stressed connections. The model report shall include color element plots with unique colors assigned to each element type and show assignments of element properties (real constants) and material properties used in the model. Auxiliary plots shall be provided as needed. Element plots showing top and bottom surface for each shell element shall be provided. The model shall be approved to SEPTA prior to performing the stress analysis. Note, that model approval does not preclude model revisions based upon the analysis results. Excessively distorted, warped, or otherwise misshapen elements which generate warning or error messages during the FEA runs shall be permitted only if the elements are not located in critical regions, are not located in high stress gradient regions, and do not adversely affect the overall results.

The Contractor shall provide SEPTA engineers with access to the FEA at the Contractor’s site at both U.S. and European facilities.

10.12.4 Finite Element and Manual Analysis Report

The FEA report, supplemented by manual analysis where appropriate, shall be submitted in paper and electronic formats and contain deflection plots for each load case with separate plots for \( x, y, z \), and overall deflection. The electronic portion of the FEA input and output results shall be submitted on CD or DVD suitable for translation by FEMAP or equal. For NASTRAN, both the binary output file with filename extensions “.OP2”, and the standard printed output file with filename extension “.F06” shall be provided. For ANSYS, the output file with the filename extension “.RST” is required. For other approved FEA codes, the Contractor shall contact SEPTA to determine the required files. Submittal is required any time the file is changed, but not more than monthly. Upon completion of the final design, the FE model and analysis report shall be updated to represent the final configuration of the structure. Criteria for final approval of the stress analysis shall include the Contractor’s submittal of the fully configured input data files.

The manual calculations shall supplement the finite element analysis and include analysis for the axles, all bolted, and huck bolted joints, and other connections and structural details as appropriate that are not readily evaluated in the FEA. The conventional analysis format consists of a title, sketch of items to be analyzed with dimensions and applied forces, drawing references, material properties, allowable stress, detailed stress calculations with references and conclusions. Forces and moments for the analysis can be obtained from the FEA.

The FEA report as a minimum shall contain: maximum and minimum principal stress contour plots; maximum and minimum principal stress vector plots showing the direction of the principal stresses; and Von Mises stress plots. Color contour stress plots for each load case showing the stress distributions in the structure shall be provided. Sufficient views shall be provided to show the stress in all portions of the model, including internal members. Stress plots showing a single color for an entire element (e.g. average element stress at centroid) may only be used to supplement the contour plots. Top and bottom surface stress shall be provided for shell element results. Nodal (averaged) and element (un-averaged)
stress plots shall be provided in order to verify mesh density adequacy. If the nodal and element stresses differ by more than 5%, the mesh shall be refined in that region, or a detailed sub-model shall be generated and analyzed to reduce the difference. Additionally, strain energy plots for the model and sub-models shall also be furnished. References shall be supplied for all formulas, calculation procedures, material strengths and like items cited where these items appear.

At the discretion of SEPTA, the finite element models and results shall be reviewed during live interactive sessions three weeks after each submittal. At these sessions, SEPTA shall have access to the FE model input and output and to the software on a computer with sufficient capability to accommodate these reviews. Optionally, at SEPTA’s discretion, FEMAP or equal general purpose finite element and solid model translating software with pre and post processing capability may be used to query the FE model features or view post-processed analysis results.

10.13 TRUCK FABRICATION

All structural members of the truck shall be steel. Low Alloy High Tensile (LAHT) steel structural shapes, plates and bars shall be used and as a minimum conform to the requirements of ASTM A588. Plate steel may alternatively conform to ASTM A 710, Grade A, Class 1, 2 or 3. Welded LAHT steel shall develop fifteen (15) ft lbs Charpy V Notch impact strength in the coarse grain heat affected zone (CGHAZ) 0.039 inches from fusion area at -20 degrees F.

Steel castings shall as a minimum meet AAR MSRP M-210, Grade “B” plus two (2) percent nickel minimum. Castings shall be heat treated to develop a minimum tensile strength of 75,000 psi, minimum yield strength of 48,000 psi, elongation of not less than twenty-five (25) percent in two (2) inches, and reduction of area of not less than fifty (50) percent. Cast steel of superior properties for a specific application may be proposed to SEPTA for review and approval.

All major bolted, threaded, keyed, or pinned connections and structurally critical locations shall be readily accessible for visual inspection. Threaded fasteners shall be SAE Grade 5 or stronger, UNC or UNF standard types, minimum 3/8 inch nominal diameter, and readily accessible without removal of truck components or the removal of the truck from the car and located to permit removal with standard hand tools. All threaded fasteners shall be retained by approved locking or prevailing torque devices.

The Contractor shall prepare and submit to SEPTA for review and approval a process and procedure to accurately and positively identify the work of each welder. Upon approval of the methodology, the Contractor shall submit this information monthly throughout the course of the production schedule.

Highly loaded welds shall be identified by the truck manufacturer and approved by SEPTA. These welds shall include, as a minimum, all welds or portions of welds which, based on the results of the stress analysis and/or truck tests, are expected to have a fatigue stress range exceeding 60% of the FTH stress in Table 2.4 of AWS D1.1, 2006. Critically loaded welds shall be identified by the truck manufacturer and approved by SEPTA. These welds shall include as a minimum all welds or portions of welds which, if a failure occurs, the truck and/or its accessory components shall not be able to perform their function. As part of the design approval, the Contractor shall provide SEPTA with drawings showing both the highly loaded welds and the critical welds.
10.14 TRUCK INSPECTION

The Contractor shall submit for review and approval an inspection and acceptance plan which includes, as a minimum, the requirements of weld inspection in Section 15.4.4. Inspection of steel castings, cast weld assemblies, and weld assemblies shall be in accordance with Section 15.7 All welding shall be in accordance with Section 15.4 Production of trucks, prior to SEPTA’s approval of the required inspection plan, shall be at the Contractor's risk.

If the first truck fails the radiographic inspection, the second shall be inspected, and this process shall continue until a truck passes the inspection. Production variables shall duplicate those for the truck which passes the radiographic inspection. As an alternate to radiographic inspection as specified, critical areas may be sectioned and etched to demonstrate weld soundness. There shall be no less than three (3) etched sections at each critical area, and the location of each shall be approved by SEPTA. Ultrasonic inspection, if approved by SEPTA, shall be performed in accordance with AWS D1.1-2006, Section 6.

After qualification in accordance with the preceding paragraph, all welds shall be subjected to magnetic particle or dye penetrant inspection. In addition, welds that are both highly loaded and critical shall continue to be inspected by radiography. Magnetic particle inspection shall be performed in accordance with ASTM E 709. Dye penetrant inspection shall be performed in accordance with ASTM E 165.

Truck frames and bolsters shall not be considered complete and shall not be run in service on SEPTA until the Contractor completes, to the satisfaction of SEPTA, all inspection requirements specified for casting and welding. Where grouping or lots are to be accepted by random sampling, all tests must be completed and the grouping or lot accepted before any of the units in the grouping or lot are considered complete or run in service.

10.15 TRUCK DESIGN LOADS

10.15.1 General

The truck frame and bolster shall be subject to the following static and fatigue loads to verify that the maximum allowable stresses, specified in TS 11.12.1 are not exceeded. The first production truck shall be used for test and FEA validation unless otherwise specifically prohibited by SEPTA.

10.15.2 Truck Static Loads

The truck frame and bolster shall be designed to resist the following static loads.

The following loads shall be applied individually, and then in combined load cases to account for the different lateral and longitudinal directions. The vertical load shall be 55% of the ready to run car body weight. The lateral load shall be the load at overturning and the longitudinal load shall be 15% of the vertical load. The lateral and longitudinal loads shall act as if applied at the center of gravity of the car body. Accessory loads, such as those from the brake units, and motors, shall represent maximum steady state conditions; i.e., maximum brake unit reactions and brake unit weights, and peak expected damper force but shall not be less than:
10.15.3 **Truck Overload**

To demonstrate that the truck has adequate strength to sustain a maximum load in the presence of a combination of minor manufacturing defects, it shall be designed to resist the following overloads statically once with all loads applied simultaneously as follows:

<table>
<thead>
<tr>
<th>Overload Design</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Truck Vertical</strong></td>
</tr>
<tr>
<td>100% ready to run car body (total) weight</td>
</tr>
<tr>
<td><strong>Lateral</strong></td>
</tr>
<tr>
<td>25% x Vertical</td>
</tr>
<tr>
<td><strong>Longitudinal</strong></td>
</tr>
<tr>
<td>25% x Vertical</td>
</tr>
<tr>
<td><strong>Tread Brake and Disc Brake Units</strong></td>
</tr>
<tr>
<td>Horizontal and vertical loads equal to the greater of two (2) times the maximum normal outboard reaction or the reaction resulting from maximum main reservoir pressure in the brake cylinder, and perfect adhesion between wheel and rail.</td>
</tr>
<tr>
<td><strong>Motor and Gear Unit</strong></td>
</tr>
<tr>
<td>Maximum. applied loads due to short circuit torque in the motors</td>
</tr>
<tr>
<td><strong>Dampers</strong></td>
</tr>
<tr>
<td>Twice the force used in the fatigue test</td>
</tr>
</tbody>
</table>

Lateral and longitudinal loads shall be applied to the truck as if they were acting through the car body center of gravity.
10.15.4 Truck Fatigue

To demonstrate that each truck type has adequate fatigue strength under dynamic loading, the truck frame and bolster shall withstand ten million cycles of combined loading.

The static vertical load shall be 110% of the ready to run car body weight with the vertical fatigue load oscillating. The lateral load shall be applied first in one lateral direction and then in the opposite direction. The longitudinal load as indicated below shall be applied first forward and then rearward. Both lateral and longitudinal loads shall act as if applied at the center of gravity of the car body with resulting vertical loading, due to transferring the loads from the center of gravity to the truck. Accessory loads shall vary between plus and minus 100% of their maximum steady state values; brake unit reaction loads shall be under full service cylinder pressure with not less than 20% available adhesion.

The phasing of loads shall be kept within 15 degrees of each other, and result in maximum combined stresses at the critical locations.

### Fatigue Test Loads

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Truck frame (and bolster, if applicable)</td>
<td></td>
</tr>
<tr>
<td>Vertical (Range)</td>
<td>+/- 20% x Ready to run car body weight</td>
</tr>
<tr>
<td>Lateral (Range)</td>
<td>+/- 15% x Ready to run car body weight</td>
</tr>
<tr>
<td>Longitudinal (Range)</td>
<td>+/- 15% x Ready to run car body weight</td>
</tr>
<tr>
<td>Tread Brake Unit</td>
<td>0 to Max Horizontal Reaction</td>
</tr>
<tr>
<td>Vertical (Amplitude)</td>
<td>Max Vert. Reaction plus 4 x TBU Wt</td>
</tr>
<tr>
<td>Disc Brake Unit</td>
<td>Max Horizontal Reaction</td>
</tr>
<tr>
<td>Vertical (Amplitude)</td>
<td>Max Vertical Reaction plus 4 x DBU Weight</td>
</tr>
<tr>
<td>Motor and Gear Unit</td>
<td>Plus/minus reaction from maximum steady state torque</td>
</tr>
<tr>
<td>Horizontal (Range)</td>
<td>Plus/minus reaction from maximum steady state torque plus five (5) times the weight supported by the truck frame</td>
</tr>
<tr>
<td>Vertical (Range)</td>
<td>The damper force that occurs when operating at the maximum expected velocity</td>
</tr>
</tbody>
</table>

Fatigue loads for truck frame-mounted equipment and associated support brackets shall be based on the weight of the equipment and a dynamic load range not less than either the maximum reaction load range resulting from normal operation, or four times the weight of the equipment supported, whichever is the higher dynamic load range.
10.16 INSTRUMENTED WHEEL SETS

Two instrumented wheel sets, and associated data acquisition and reporting software and hardware shall be provided to SEPTA to acquire continuous longitudinal (traction), lateral and vertical wheel/rail forces from one truck. These instrumented wheel sets must use the AEM-7 wheel profile. The primary use of the wheel sets shall be to determine the safe operating envelope of the vehicles by verifying high-speed stability, safety of high cant deficiency operation, and measuring operating wheel/rail forces per TS 11.3 and assuring compliance with the FRA Standards. The maximum operating speed of the wheel sets shall be 135 mph, and the minimum life including strain gauge attachment and protective coating shall be twelve years. As a minimum, wheel sets must meet the requirements of AAR MSRP Appendix B, Specification for Instrumented Wheel sets for Chapter XI (M-1001) Testing and FRA part 213.345 qualification testing. The wheel sets shall be supplied with individual hardwood crates for shipping and storage. The crates shall have wheel-tread cradles that conform to the wheel diameter. The axle ends shall be secured with non-metallic tie-down straps. Data acquisition shall be done with a high-speed digital system using commercially available computers and related components for data acquisition storage and display. The system must be capable of providing real time display of stop test safety criteria, and near real time reporting of measurements.

The wheel sets shall be the same size, material and tread profile as the wheels supplied on the vehicles. Milling of the wheel sets to improve sensitivity shall be allowed as long as the final dimensions remain within AAR limits.

The lateral and vertical wheel forces shall be measured with the measurements processed through a low pass filter with a minimum cut-off frequency of 25 Hz. The sample rate for wheel force data shall be at least 250 samples/sec. The operating ambient air temperature range shall be no less than 0 to 110 degrees Fahrenheit. The actual operating temperature range shall be noted, as well as any temperature restrictions. All raw data channels shall be pre-amplified to a minimum of 1 volt peak-to-peak at a nominal 80% load on the wheel side of the slip rings.

The longitudinal, lateral and vertical outputs shall be within 4% of the actual applied load, or within 250 lb, whichever is greater. This accuracy shall be over the entire range of applied loads, over the range of lateral to vertical (L/V) and traction to vertical (T/V) values, and around the full 360 degrees of rotation. This accuracy shall be maintained under conditions of high angles of attack and during two-point wheel/rail contact. This accuracy shall be demonstrated in an approved loading fixture or fixtures. Testing and documentation in support of this accuracy shall conform to Sections 3 and 4 of AAR MSRP Appendix B, Specification for Instrumented Wheel sets for Chapter XI (M-1001) Testing, and submitted to the Engineer for approval.

Initial vehicle testing may be accomplished at Transportation Test Center Inc. in Pueblo, Colorado, and on portions of Amtrak NEC or SEPTA trackage deemed appropriate for the testing. Qualification testing shall be performed on SEPTA’s facility. The Contractor shall provide personnel for conducting the initial and qualification testing. Sufficient documentation, training, software and equipment shall be provided to SEPTA to allow future use of the wheel sets by qualified technicians.

END OF SECTION
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11 FRICION BRAKE EQUIPMENT

11.1 GENERAL

11.1.1 Overview

This Section defines the requirements of the friction brake system of the Locomotive and its interface coordination with propulsion (Section 9) and cab signal/SEPTA PTC system and Event Recorder systems (Section 12). The friction brake equipment shall be designed and manufactured to comply with the materials, design, workmanship, test, and any other relevant sections of the Specification.

The locomotive shall be equipped with any combination of tread brake units, disc brakes and wheel mounted cheek brakes as required in this Specification. The locomotive shall also be equipped with an electric brake system incorporating regenerative and rheostatic features. All three braking elements shall be blended for operation as described in this Specification. Tread brakes, if applied, shall be limited to providing less than fifteen percent (15%) of the friction brake capacity, or the level which produces a tread surface temperature of 600 °F under worst-case conditions, whichever is less.

A wheel slip/slide detection and control system (as described in Section 9.9.3.) shall be provided.

The air brake system shall have the ability to operate in graduate and direct release operations at 90 and 110 PSI brake pipe pressure.

The brake control system shall be a 26C-CS2 compatible, microprocessor based system such as a Knorr-NYAB CCBII, Wabtec Fastbrake, or SEPTA approved equivalent. The brake system supplied shall meet all requirements of 49 CFR 231, 49 CFR 236, and 49 CFR 238. All key control and foundation brake components shall be service-proven.

The brake system and the individual components, other than generic standard materials, shall be supplied by an experienced air brake equipment supplier who has confirmable previous satisfactory operating experience on North American commuter railroad passenger systems.

11.1.2 Responsibility

Contractor shall provide an integrated brake system using service-proven, reliable components. The Contractor shall provide a listing of the major components proposed, indicating their previous service history. The entire brake system supplied on these locomotives shall be the responsibility of the Contractor and subject to SEPTA Design Review.

Where options exist, SEPTA reserves the right to approve specific components and materials on a case-by-case basis based upon SEPTA experience and previous service history. SEPTA may require that the brake components be sourced from multiple suppliers as part of this requirement.
11.1.3 System Description

The friction brakes shall be an integrated system operated from the locomotive cab. The system shall be designed for operation at all speeds as specified in Section 2.2.7.1. Friction brakes shall respond to brake pipe pressure which is electronically controlled from the locomotive cab in response to total brake command and available electric brake.

The friction brake system shall be the supplemental system during blended service braking as well as the sole braking system when electric brake is not available. The system shall be designed and manufactured to provide the highest levels of safe operation, reliability, and ease of maintenance.

A locomotive independent brake application and release, with bail-off function, shall be included. Bail-off function shall not release locomotive brakes during penalty or emergency braking.

Control of the brake system shall be a 26C-CS2 system. The system shall be fail-safe and stopping distances, as specified in Section 2.2.7.3, shall be achieved using friction brake only with the electro-pneumatic control and electric braking functions disabled.

Tread brake capacity shall be limited as required by Section 10.1.1. Disc material, number, and mounting arrangement shall be determined by the Contractor and shall be subject to SEPTA approval.

The brake system design shall allow a disabled locomotive's pneumatic brakes to be controlled by a conventional locomotive during rescue operation, through brake pipe control alone. Main reservoirs shall be able to be charged through a dead engine feature.

The total friction brake system shall include an air supply system, reservoirs, pneumatic control devices, control logic, foundation brake equipment, and all accessories necessary to control retarding torque in response to the electrical and pneumatic control signals specified. The system shall be designed to operate compatibly with all specified interfaces and operating conditions, including but not limited to, the electrical power supply systems, the propulsion system, the cab signal and SEPTA PTC system and the environmental requirements with regard to stop distances, jerk limiting, blending, and slip/slide as defined in this Specification. The system shall also be designed with regard to maintainability, safety, and reliability as defined in this Specification. The friction brake system shall perform the following basic functions:

11.1.4 Service Blended Braking

Supplement electric brake to provide service-blended braking as commanded by the brake controls. Refer to Section 2.2.7.7 for performance requirements and Section 10.9.7 for electric braking criteria.

11.1.5 Service Friction Braking

Provide service friction braking in the event of electric brake failure, as commanded by the brake controls. Refer to Section 2.2.7.3 for performance requirements.
A snow brake function shall be provided that applies a minimal brake shoe and pad force to eliminate snow and ice buildup on the tread brake units and disc brake units. The snow brake shall be controlled from the Engineer’s cab console.

11.1.6 Emergency Braking

Provide for pneumatic only emergency braking as commanded by the pneumatic brake trainline or brake controls. The performance requirements for emergency braking are given in Section 2.2.7.7.

11.1.7 Rescue and Tow Braking

Provide for service and emergency braking as controlled solely by brake pipe pressure, with the electro-pneumatic brake cut out, for use when the electric locomotive is being moved by a conventional locomotive. The brake system shall be capable of being recharged from the brake pipe.

11.1.8 Parking Brake

Provide a spring-applied, air-released parking brake control signal to unit car in the train consist which shall be controlled from the active locomotive cab. The parking brake shall comply with the requirements of Section 11.6.

11.1.9 Compressed Air Supply

Supply clean, cooled, dry compressed air for the friction brake system and to other train consist systems.

Nominal air brake pressures shall be as follows:

- 140 psig Main Reservoir;
- 110 psig Brake Pipe;
- 100 psig Brake Cylinder maximum.

The friction brake system shall be leak-tight and have sufficient air storage capacity, after loss of compressor drive power, to allow for three brake applications and releases under conditions of maximum air usage and minimum adhesion. Full brake applications shall assume all-friction operation (no electric brake) at a brake cylinder pressure equivalent to full service rate. It shall be assumed that the power loss occurs when the main air reservoir is at its minimum service pressure level of 130 psi. Compliance with this requirement shall be demonstrated before final determination of air storage capacity by means of a detailed air consumption analysis which includes allowance for wheel slip/slide protection system activity. This design shall be verified and proven by test of the first locomotive.

11.2 POWER SOURCES

The friction brake electronic control equipment and accessory magnet valves shall operate on the Low Voltage DC Power system described in Section 8.11. The equipment shall be able to function normally
between the maximum and minimum voltages specified in Section 2.2.8.1. The air compressor drive motor shall be powered from the locomotive's auxiliary power system described in Section 8.1.

11.3 BRAKE CONTROL SYSTEM

11.3.1 General
The 26C-CS2 brake control system shall consist of a service-proven, microprocessor-based brake control system, including comprehensive diagnostics and fault monitoring. The friction brake control system shall be functionally and operationally compatible with 26L brake equipment and be capable of operating in MU with SEPTA's existing locomotive and control car fleets.

11.3.2 Service Brake Control
Train braking commands shall be initiated from the locomotive. The control system shall be designed to prioritize the use of the electric locomotive's electric brakes up to their maximum capability, and use friction braking as required to supplement electric brake up to the total commanded brake requirement. The total brake command shall be communicated to all locomotives in the consist and electric braking shall be applied as described in Section 9.8.20.3.

The trainlined brake command shall immediately provide initial friction brake cylinder pressure to all brake equipment. Initial braking shall be determined by the brake computer logic, based on the total brake command and the anticipated electric brake contribution. When anticipated electric brake contribution exceeds the total brake command, in-shot brake cylinder pressure shall be provided. When anticipated electric brake contribution is less than total brake command, the initial braking shall equal the computer-determined required friction supplement. A method of indicating the electric brake tractive effort being provided by the locomotives shall be communicated to the controlling cab's brake control computer where it shall be compared against the total brake command.

The Contractor shall provide control logic necessary to assure smooth integration of the friction brake, and wheel slide equipment and shall coordinate electric and friction brake blending to assure that the brake build-up response does not exceed the maximums required in Section 2.2.7.5, regardless of the electric brake availability. Control logic on the locomotive shall limit locomotive friction brake to the locomotive’s adhesion limit when electric brake is active.

Electro-pneumatic overlay propagation control (EP) of the brake pipe reduction shall be provided, however, a loss in electro-pneumatic braking control shall not prevent the locomotive and consist from achieving operating braking rates.

The contractor shall integrate the brake system with the requirements of Section 12.0 ATC, PTC, and Event Recorder Systems.

The electronic brake system shall have power-up and continuous system self-diagnosis capabilities and a non-volatile system status and fault logging memory. Compromise of the computer’s functional integrity, or detection of excursions outside of established tolerances for safety critical commands, shall
result in a full service application. The Contractor shall provide a full Failure Modes and Effects Criticality Analysis (FMECA) for the friction brake system.

The system shall have the ability to perform self terminal testing under the direction of the operator conducting locomotive terminal brake testing.

The control system diagnostics shall be designed to capture all faults, count operation cycles of key components, perform trend analysis of faults, and gather additional operational data to generate predictions of when electronic, electro pneumatic, or pneumatic components shall exceed established performance limits. The system shall indicate recommended removal of the appropriate components prior to actual deviation of performance beyond those limits. When performance limits are being approached, the recommended service operation should be annunciated to the engineer on the locomotive's monitoring system and by LDMS to alert service personnel at the end destination.

Computer-driven system design and hardware arrangements shall preferably have documented service experience in the intercity or mass transit industry. Documentation shall include previous failure modes. History shall include warranty and non-warranty events.

Local (per locomotive) cut-out of electronic brake or train line control shall be provided, however, cut-out shall not impair the function of the pneumatic brake system on that locomotive.

### 11.3.3 Emergency Brake Control

A pneumatic emergency brake application shall be obtained throughout the consist from any of the following, initiated in the locomotive or at any location in the consist.

- Conductor's emergency valve;
- Emergency brake rate brake pipe reduction;
- Parting of the consist or rupture of the brake pipe;
- Engineer's Controls - Emergency Position;

Engineer-initiated emergency brake application shall have a minimum of two parallel independent paths for transmitting the emergency brake command by means of the Engineer's controls (pneumatic and electric). The pneumatic venting device may be piloted from the controller. The direct venting device and the electro-pneumatic venting device shall both be located on the brake manifold;

In each of the preceding cases, the Brake Pipe shall be vented to initiate emergency braking.

An emergency brake command from any location in the consist shall immediately without jerk rate limitation, initiate the application of emergency braking throughout the consist, and shall be so arranged as to shut off the propulsion power on all locomotives simultaneously at the instant that an emergency reduction is sensed on any location in the consist.
All air exhaust shall be vented external to the locomotive cab interior. A brake pipe charging cut-off feature shall be provided.

Automatic sanding as specified in Section 5.13 shall be provided in all cases of emergency braking. Emergency brake shall consist of all friction brake with no wheel slide control. However, a means shall be provided to the Engineer to manually add wheel slide protection for instances that are not an emergency.

The air brake system shall provide rapid response to an emergency brake command in accordance with the requirements of Section 2.2.7.7 at all times. The system shall permit prompt recharge of the brake pipe in accordance with Section 2.2.7.5 after an emergency application when the train has stopped, and the vent valves have closed. Two brake pipe vent valves shall be provided and located according to valve supplier’s recommendation. Vent valves shall close no less than 60 seconds after the emergency application. Brake pipe pressure shall recover to at least 80 psig before traction power may be applied.

### 11.3.4 Power Knock-Out (Graduated release operation)

The brake system alone shall provide electrical interlocking to remove traction power in the event of a Penalty or Emergency brake command. Power knock-out shall not be affected by the brake applied/released circuits; however, a non-released brake shall be annunciated in the controlling locomotive cab.

### 11.4 AIR SUPPLY SYSTEM

The air supply system shall be designed to provide cooled, dry, clean compressed air to the consist for friction braking and auxiliary pneumatic devices, including sanding. Discharge of all drain valves shall be deflected in a safe direction away from the ground. All electrical control and sensor connections to the air supply system components shall utilize heavy-duty, multi-pin electrical connectors in accordance with the requirements of Section 15.23. The air supply system shall comply with requirements of 49 CFR 229.49.

### 11.4.1 Air Compressor

An air compressor shall be provided on each locomotive. Each air compressor’s total capacity shall be a minimum of 120 SCFM at 140 psi discharge pressure.

The compressor shall be the rotary screw type. Direct reading temperature gauges (air, oil, temperature, etc.) shall be provided at the same location as the sensors for remote temperature monitoring. Use of control piping shall be minimized by use of internal parts, all piping shall be fireproof.

A high reliability (six year minimum life) NEMA C flange coupling, shall be provided between the compressor and the drive motor. The compressor design shall not overload the motor during starting under cold ambient conditions, with temperatures as specified in Section 2.2.5. The compressor shall use a high flash point, commercially available, non proprietary, lubricating oil as specified by the compressor manufacturer. Low oil shut down protection shall be provided.
All compressor hose connections shall utilize wire-reinforced flexible hose in accordance with Section 11.5.4.10. The discharge hose shall be rated for a minimum of 220°F.

11.4.2 Compressor Motor

The compressor drive motor shall be an integral part of the total assembly. It shall be powered from the locomotive auxiliary power system described in Section 8.0. The drive motor shall be one which limits starting current to within industry recommended practices. The compressor motor shall be equipped with NEMA C-frame type sealed bearings that shall not require re-lubrication for the life of the bearing. Bearings shall be sized to provide a six-year life. Power and control wiring shall be by means of separate multi-pin power and control connectors respectively. The connectors shall comply with the requirements of Section 15.23.

The compressor motor stator insulation shall be IEEE Standard 11, Class H insulation system or better. After assembly, the motor stator coils shall be vacuum pressure impregnated (VPI) in the complete stator frame assembly. A description of the proposed VPI shall be included in the Contractor’s proposal. The stator shall be arranged to permit rewinding. The rotor shall be arranged to permit replacement of the shaft without damage to the rotor.

11.4.3 Compressor Control

The air compressor governor control shall be integrated into the brake control electronics as part of the brake control system. The control shall be designed for on-demand (on/off) control and not a continuous running/modulated choke control method and shall be set to maintain the pressures specified in Section 11.1.9. A discharge overpressure safety relief valve shall be provided to limit system pressure to 150 psig. The reset pressure differential of this device shall not exceed 20 percent of the relief setting. Compressor control circuitry shall be protected by a circuit breaker located in the cab, and AC voltage control relays shall be used whenever practical. Governor switches shall be used for start/stop and pressure switches for 145 psi high and 135 psi low pressure regulation.

11.4.4 Air Cooling System

The compressed air cooling system shall consist of a heat exchanger and all related accessories. The heat exchanger shall be provided with a non-field adjustable overpressure relief device. The system shall not be susceptible to blockage by ice in the event of failure or manual shutoff of the automatic drain system. The heat exchanger shall be arranged to drain into the sump reservoir. The sump reservoir shall be equipped with a thermostatically-controlled, heated, automatically-timed, pneumatically-piloted drain valve with a manual operation and manual shut-off feature. The timer, thermostat, and similar control functions shall be integrated into the electronic controls of the brake manifold, not discreet devices in the drier system. The drain valve heater shall be operated from the thermostatically-controlled protective heater circuit. The heat exchanger shall be designed to provide discharge compressed air within 10°F of ambient air temperature.

11.4.5 Desiccant Dryer

The air supply system shall include a twin-tower type desiccant drier assembly controlled by an electronic cycle timer integrated into the brake manifold electronic controls. An optional desiccant
memory feature shall be provided. The desiccant material shall be under spring compression to minimize the generation of desiccant dust. The unit shall meet the air quality requirements of APTA SS-M-011-99. The assembly shall be equipped with an air filter, oil coalescer and a humidity indicator. Oil content of discharge air shall not exceed 25 PPM. Each tower shall have a sump with an automatic, heated drain valve that shall completely discharge the contents of the sump. A qualification test shall be run to verify compliance with the stated air quality requirements under maximum cycling conditions in conjunction with the air compressor capacity verification. Dryer shall be a Salem 994 or SEPTA approved equivalent.

11.4.6 Low Main Reservoir Pressure Protection
Control shall be provided to automatically cause a penalty brake application if either main air reservoir pressure falls below 90 psi. The control function shall be nullified if the brake system is de-energized or when the locomotive is disabled and being towed by another locomotive.

11.4.7 Air Reservoirs
Except for small reference volumes and similar small volumes, all reservoirs shall be supplied by the manufacturer with drilled "telltale" holes in accordance with 49 CFR 229.31. All reservoirs shall be designed to withstand at least five times maximum working pressure. Air reservoirs shall meet the requirements of Section VIII for ASME Pressure Vessels and shall comply with all applicable FRA requirements. The use of aluminum reservoirs shall not be permitted.

An auxiliary reservoir shall be provided. Connections to the auxiliary air reservoirs from the main reservoir trainline shall be at a higher elevation than the main reservoir trainline.

Critical auxiliary air devices such as pneumatic propulsion actuators and similar items which are essential to safety or reliable train operation shall have a separate, check valve protected supply reservoir sourced from the main reservoir, sized to meet all relevant FRA requirements.

Each locomotive shall be equipped with two main reservoirs piped in accordance with standard AAR recommended practice. Each main reservoir shall have a minimum volume of 30,000 cubic inches. Main reservoirs shall be provided with overpressure safety relief valves and heated auto-manual drain valves with a manual shut-off feature which is activated on a timed cycle as controlled by the integrated brake system control, and not a separate control device. Manual drain valves shall be freely accessible by service personnel from the side of the locomotive. The main reservoirs shall be mounted to provide a one inch slope from end to end with the drain cocks located at the lowest point. Drain valves shall be protected from flying debris.

A safety valve meeting the requirements of 49 CFR 229.49 set at 150 psi shall be located at the number 1 main reservoir inlet.

11.5 FRICITION BRAKE EQUIPMENT
This section defines specific hardware requirements for the friction brake system components.
11.5.1 General

The pneumatic control system shall consist of all devices necessary to actuate the foundation brake equipment in response to the trainlined pneumatic and electric brake commands. All branch connections from the main reservoir or brake pipe trainline pipes shall utilize AAR type branch pipe tees.

11.5.2 Maintainability

All electronic and pneumatic brake control devices to the extent practical shall be incorporated onto a single common manifold on each locomotive.

All components shall have sufficient clearance for easy removal of any portion, or the complete component, without removing or disconnecting adjacent equipment.

Under-floor-mounted portions of the air system which may require frequent attention such as drain cocks on reservoirs, test fittings, and filters, shall be accessible from the side of locomotive. Access to all maintenance items, including those mounted above-floor, shall be subject to SEPTA review and approval.

All renewable air brake components including check valves, magnet valves, filters, chokes, and all other devices shall be manifold-mounted, unless otherwise submitted and approved. Subject to case-by-case review, exceptions may be considered for devices whereby the serviced portion may be easily removed from the device, without disturbing the piping. Where exceptions are granted for items which shall be in-line mounted, pipe connections shall be joined by a connection which provides a reliable seal and allows easy component removal and replacement.

Air test fittings and electrical test jacks and connectors shall be provided to allow for fault isolation and periodic functional and calibration checks of components and systems without requiring the disconnection of air lines or electrical cables. Test fittings and jacks shall be accessible and shall be placed in protected locations.

11.5.3 Service Life

Pneumatic and electro pneumatic hardware components shall have minimum service life of eight and 1/2 years, based on a minimum duty cycle of 30,000 brake applications and releases per year. Wheel slip correction devices shall be designed for a minimum duty cycle of 250,000 events per year.

11.5.4 Pneumatic Devices

11.5.4.1 Check Valves

All check valves shall be soft seated.

11.5.4.2 Brake Control Unit

The pneumatic brake control unit shall be designed for graduated release with capability for easy conversion to direct release when needed. The graduated release function shall retain corresponding
brake cylinder pressure control throughout the entire control range down to within 5 psi of the full release brake pipe pressure. Control hysteresis between brake pipe pressure and pre-control pressure shall be no more than 2 psi for application and release. The unit may facilitate the transmission of quick service and quick action through local exhaust of the brake pipe. The brake control unit shall be capable of providing a full brake application no more than 5 seconds following a full release.

Except for emergency brake vent valves remotely mounted auxiliary devices for quick service and quick action brake pipe control shall not be permitted.

The brake control unit shall provide inshot brake cylinder pressure (as a minimum) with all service brake applications. The brake control unit shall be designed to operate as intended with a brake pipe pressure setting between 90 - 110 psi.

### 11.5.4.3 Brake Manifold

All electronic and pneumatic devices shall be incorporated onto a common manifold.

The pipe connections to the manifold shall be at an elevation higher than the main reservoir or brake pipe respectively.

The brake manifold shall be mounted in the vertical plane, completely enclosed, and elevated above brake pipe center line in an area which permits free access by maintenance personnel. The locomotive shall have only one brake manifold. Test points shall be compatible with SEPTA’s standard test apparatus. Any removable manifold module shall not weigh more than 35 lbs.

Stud-mounted air brake components such as air brake portions, valves, and cocks shall be secured to manifolds with standard, non-self-locking nuts. Unless approved by SEPTA, full-face gaskets shall be used in lieu of O-ring gaskets for valve portion interface sealing. All stud-mounted components shall be designed to allow installation or removal with standard sockets.

Electronic modules, pneumatic modules, cut outs, test points, and electrical connections shall be front-plane-mounted on the manifold. All power, input, and output connections external to the manifold shall be provided with multiple pin connectors in accordance with the requirements of Section 15.23. Connections to magnet valves shall use encapsulated plugs. Individual spade-type, threaded, or ring connectors are not permitted. Valves, connectors, and components shall be identified on the manifold with a permanent nameplate.

### 11.5.4.4 Brake Controller

The brake controller shall be a console style unit with a single, non-removable operating handle. The handle movement shall be in a longitudinal (front-back) direction, with the release position closest to the Operator. The controller shall be a combination electric and pneumatic unit. It shall include a vent valve for redundant venting to the outside of the vehicle of the safety control pipe (number 21 line) during an emergency brake application. Braking effort shall be continuously variable between minimum application and full service.

The operating handle shall have the following positions, from front to back:
• Handle Off
• Emergency
• Full Service Reduction
• Suppression
• Minimum Service Reduction
• Release

An Electric Hold functionality shall be provided by lateral movement of the handle to the right in any position between Full Service to Release, inclusive. Each of these lateral positions shall have a detent and shall control the brake pipe trainline.

Dry, fail-safe, electrical contacts shall be provided to interface with the cab signal system. The contacts shall be vital to close only in suppression or greater application positions, taking into account possible failure of the electric brake. When the brake control lever is in the suppression or greater application positions, a "Suppression" indication shall light on the Engineer's screen.

A locomotive independent brake application and release, with bail-off function, control lever shall be mounted to the right of the brake controller lever.

11.5.4.5 Air Gauges

Integrated electronic pressure indicators shall be provided in the cab display monitor as described in Section 5.0. Alternately, analogue air gauges shall be provided on the cab console.

11.5.4.6 Pressure Test Fittings

Salem-type or equal pressure test fittings shall be provided in air lines to gauges, pressure switches (where permitted), pressure-to-electric transducers and any other apparatus requiring calibration and checking. Test fittings shall be provided on the brake manifold to monitor Main Reservoir, Brake Pipe, Brake Cylinder and Auxiliary Air Pressure.

The fittings shall be clearly labeled and shall allow for simple and effective accuracy and calibration testing without removing the item being tested from the locomotive. Where in-line fittings are used, it shall be possible to perform testing while the system is fully charged through the use of an automatic shut-off valve, integral with the test fitting. The valve shall, upon insertion of the test apparatus, close off the normal supply line to the component being tested. Fittings shall be close-coupled to the device which each serves and shall be mounted in an approved, accessible, and protected location.

Tee type test fittings shall also be provided at all key pressure-monitoring locations including, but not limited to, main reservoir, brake pipe, and brake cylinder (all axles).

11.5.4.7 Electrical/Electronic Devices

Refer to Section 15.25 for the design criteria for electrical/electronic devices.
11.5.4.8 Electro-Pneumatic Control Equipment

If provided, to be defined by Contractor to meet the specified performance criteria.

11.5.4.9 Cut-Out Cocks

Unless specified otherwise, all cut-out cocks shall be the side-vented ball type. Cut-out cock handles shall be the spring-loaded locking type. Except for the brake pipe cut-outs, all handles shall be arranged so that in the closed position they shall be parallel with the flow of air and in the open position perpendicular to the flow of air. The brake pipe cut-out handles shall be oppositely oriented in accordance with normal railroad practice. Cut-out cocks shall be installed in a position such that gravity shall not cause the valve handle to vibrate to the opposite position in service upon a failure of the locking mechanism. Also, unless otherwise specified, all likewise-oriented cut-out cock handles shall be installed in a consistent manner such that open and closed handle rotation is always in the same direction.

All valves and cocks shall be identified including the cut-in and cut-out positions.

11.5.4.10 Brake Cylinder Cut-Out

A vented, ball-type cut-out cock, accessible from the locomotive exterior shall be provided in the brake cylinder line to each truck to cut out pneumatic braking on that truck. Access shall be close to the affected truck. Each truck brake cylinder cut-out cock shall have annunciated position.

11.5.4.11 Trainline Cut-Out Cocks

Vented, ball-type cut-out cocks with locking handles shall be provided on all inter-unit pneumatic connections on both ends of each locomotive. Standard AAR main reservoir and brake pipe angle cocks shall be provided on each end of the locomotive.

11.5.4.12 Lines, Hoses and Fittings

Refer to Section 15.19 for pipe requirements.

All connecting hoses shall be AAR M618 wire reinforced hose. Inter-unit connection hoses shall be AAR M618 with a steel-armored outer jacket and shall have swivel-threaded connectors. Minimum nominal hose size shall be 1-1/4 inch brake pipe, 1 inch main reservoir. Inter-unit hoses shall be installed as high as possible above the running rail to minimize damage potential.

Hoses for brake pipe and main reservoir air with AAR-compatible glad hands shall be provided at both ends of the locomotive. Type F and Type L vented dummy couplings shall be provided for hoses at both ends of the locomotive.

11.5.4.13 Tread and Disc Brakes

A. Tread Brakes
Individually-actuated, truck-mounted tread brake units with automatic slack adjusters shall be
designed for application to all wheels and shall be provided as required in Sections 11.1.1 and
11.1.3. The design shall allow the application of at least two different suppliers' tread brake
units to be fitted interchangeably. Truck-installed mounting brackets shall be applied to each
wheel position of the locomotive.

Units shall be designed for installation on the truck frame in a manner to provide for ease of
removal and replacement of brake shoes. Final connection to the tread brake units shall be a
hose connection and shall not interfere in any way with the removal of the brake key, nor shall
any surrounding structure or appurtenance impede brake shoe removal or replacement.

Bushings, pins, and other components that normally require lubrication shall be supplied with
permanently lubricated, sealed grease cavities which provide a minimum 6 year life. If this
feature is not available, grease fittings shall be provided.

Grease fittings shall be oriented or protected in an SEPTA-approved manner to minimize
potential damage from dirt contamination, roadbed debris, or brake shoe replacement.

B. Slack Adjusters
Tread brake and disc brake units shall have automatic slack adjusters designed to maintain the
design positive clearance between the brake shoe/pad and wheel/disc during brake release over
the full wear range of the friction brake material. The automatic slack adjusters shall also be
designed to allow for manual adjustment of shoe/pad position when replacing shoes or pads.
The manual adjuster release mechanism shall be designed to revert to the normal operating
mode without any special action by the mechanic following service activity. Free access to
adjuster shall be provided with adequate freedom of movement by the adjusting tool.

C. Tread Brake Shoe Application
The design of tread brake units shall permit the use of un-flanged brake shoes designed to meet
the intended purpose. Flange-bearing brake shoes are not permitted. Lugs shall be provided to
maintain lateral shoe alignment. Lateral alignment provisions shall be designed such that friction
material interface with the wheel tread is limited to the wheel/rail rolling contact area.

D. Brake Shoe/Pad Design
Tread brake shoe and brake disc pad composition material shall be as selected by the brake
system supplier to best meet the performance requirements of this Specification. Temperature
fade, glazing during periods of dynamic brake, and fade due to wetness and dampness shall be
minimized. Tendencies for metal pick up shall also be minimized.

Friction brake material selection shall consider the consistency of performance throughout the
range of design, minimization of wheel and disc peak temperatures and wheel tread cleaning
characteristics.

E. Disc Brakes
Disc brakes or wheel-mounted cheek brakes shall be provided on each axle of the locomotive.
Split discs are permitted.
Brake discs shall be ventilated and designed to operate in the intended service without requiring additional equipment for heat dissipation.

Brake discs shall have a minimum service life of the lesser of eight and ½ years or 1,400,000 miles.

The air-actuated caliper assembly shall be equipped with an integral automatic slack adjuster and shall be mounted on the truck frame. The disc brake actuator assembly shall have a minimum service life of the lesser of 1,400,000 miles or 8 1/2 years. Air connections shall be by hoses, not hard-piped. Disc brake calipers shall have slack adjusters as required in Section 11.5.4.13.B.

Locking devices shall be provided on pad holders to provide positive retention of brake pads. Brake pads shall be replaceable without removal of the disc brake caliper.

Brake disc pad composition material shall be as selected by the brake system supplier to best meet the performance requirements of this Specification. Temperature fade, glazing during periods of dynamic brake, and fade due to wetness and dampness shall be minimized. Tendencies for metal pick up shall also be minimized. The brake pad selection shall consider the consistency of performance throughout the range of design, minimization of friction disc peak temperatures under air-only service and emergency braking.

F. Brake Indicators
Pneumatically-operated, high-reliability indicators for each truck shall be designed and applied to operate from the brake cylinder and parking brake control line between the cut-out cock and the controlled axle. The indicators shall be designed to achieve a failure rate of less than 2 percent with a confidence factor of 98 percent within SEPTA's regularly scheduled maintenance interval.

The indicators shall be readily visible from track side and high platforms from either side of the locomotive, and shall indicate if the service and parking brakes are applied or released. A test fitting shall be provided in each brake cylinder and parking brake control line to the trucks. Indicators shall be protected from flying debris.

Brake status sensing for each truck shall be provided by the integrated brake control system to interface with the trainlined electrical indicating system.

### 11.6 PARKING BRAKE

A spring-applied, air-released parking brake shall be provided using a sufficient number of truck mounted brake units to hold a fully serviced and “ready to run” locomotive indefinitely on a 3% grade. Testing to verify this requirement shall be conducted using new brake shoes and pads. A manual mechanical release for each truck's parking brake shall also be provided. The mechanism shall be protected from damage by debris. The released state of the manual mechanical release shall be visible and verifiable from either side of the locomotive. Operation of the mechanical release shall not require the use of a tool and shall not require more than 15 pounds force to operate. Access for the manual release mechanism shall be from both sides of the locomotive. The brake shall automatically reset to the
normal operating condition when air brakes are re-applied after use of the mechanical release feature. Moving the unit dead in tow, shall not require any special operation other than moving the parking brake control to the release position assuming the locomotive air system is charged by the rescue locomotive.

The consist parking brake function shall be activated and deactivated at the controlling cab by means of a switch on the control console. A SEPTA-approved method of cutting out individual parking brakes on the locomotive shall also be provided from the exterior. The cut-out state of a truck parking brake shall be visible from either side of the locomotive.

Positive indication of the parking brake status shall be provided to the controlling cab via trainline 14 of the MU receptacle.

Parking brake shall be interlocked with the propulsion system as required in Sections 9.8.4.3 and 9.8.5.

11.7 WHEEL SLIP/SLIDE PROTECTION SYSTEM

The wheel slip/slide protection system shall work in conjunction with the propulsion system as found in Section 9.8.3.

11.7.1 Wheel Slip/Slide Release Valves

One wheel slide control (dump) valve shall be provided for each axle set of friction brake units to modulate brake cylinder pressure at the command of the wheel slide detection system. The reapplication of pressure following a release shall be appropriately choked, timed, or otherwise modulated to maximize the use of available adhesion without excess air usage.

11.8 BRAKE TEST RACK

Pneumatic components shall be capable of being tested on a railroad industry standard AB type test rack. The Contractor shall provide test schedules and any cables, hoses, adapters and fittings necessary to perform testing on a standard test rack.

The electro pneumatic and digital logic driven components shall also be capable of being tested in conjunction with pneumatic components of the friction brake equipment of the locomotive. The Contractor shall provide test equipment to perform this function. The design and operation of such test equipment shall be suitable for SEPTA use.

Test procedures shall be provided by the Contractor to SEPTA for testing and maintaining the friction brake equipment of the locomotive.

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16 TESTING

16.1 GENERAL
As part of the production of the locomotives under this Contract, the Contractor shall be responsible for a comprehensive series of tests to be performed to verify both the suitability of design and workmanship of each locomotive. These tests are to be performed to ensure compliance with Specification requirements, confirm the elimination of deficiencies, and to provide data on locomotive operating characteristics. The Contractor is also responsible to fulfill all requirements called for by the Federal Railroad Administration for testing passenger equipment which has not been used in revenue service, per the requirements of 49 CFR 238.111(b) for Tier I equipment, for submission by the Engineer to the FRA.

The tests and any required adjustments to be performed are grouped into three classifications: Engineering, Production Conformance and Vehicle Acceptance Tests. Whenever test requirements overlap, the more comprehensive shall govern. The Contractor shall perform all tests under Engineer observation, and the FRA may also observe such tests. The Contractor’s engineering departments shall also be responsible for providing assistance and expertise during performance of tests and for preparation of related test reports. It shall be the responsibility of the Contractor’s engineering departments to develop procedures for the vehicle tests to be conducted. All contractual tests shall be conducted in accordance with Engineer approved test procedures. Testing activity scheduled and/or conducted before test procedure approval will be at the Contractor’s risk.

16.2 TESTS

16.2.1 Classification
The following types of testing shall be conducted:

Engineering (Proof-of-Design):
The Engineering Tests (Sections 16.4 through 16.7) consist of all Pilot Locomotive component, system and locomotive and train tests to be performed at the manufacturer's facility "pre-productions", Contractor's facility "pre-delivery" and SEPTA's facility "on-site functional and operational" to demonstrate conformance with the Technical Specification requirements and establish the baseline configuration. All components used for endurance testing shall be scrapped upon the conclusion of testing and not incorporated into a locomotive.

Production Conformance:
Production Conformance Tests (Sections 16.8 and 16.9) consist of all component, subsystem, system and locomotive tests to be performed on production locomotives on an ongoing basis. These comprise component level testing at the manufacturer’s facility.
"production", and locomotive level testing at the Contractor’s facility "pre-delivery" to demonstrate conformance with Technical Specification and baseline configuration requirements prior to delivery.

Acceptance Tests:
These tests consist of all Locomotive Acceptance Tests (see Section 16.10) performed to demonstrate compliance with the Technical Specification requirements and acceptance criteria established on the basis of engineering/proof of design testing. Acceptance tests are to be performed on each locomotive by the Contractor at SEPTA's facilities. The successful completion of all acceptance tests is a condition for Acceptance.

16.3 REQUIREMENTS

The Contractor is required to perform all tests as specified herein. The Contractor and its subcontractors may, at their option, perform additional testing as they deem necessary as part of the quality assurance program. Unless indicated otherwise, all costs associated with any of the tests performed are to be borne by the Contractor. In the event of a failure to meet the Technical Specification requirements in any test, necessary corrections shall be made by the Contractor at its expense, and the failed test shall be rerun in its entirety at the Contractor's expense. If further corrections or modifications affecting the item under test are instituted, the Contractor shall perform a complete retest at its expense to demonstrate compliance with the Technical Specification requirements. The Contractor shall give at least ten working days notice to the Engineer prior to the start of any test referred to herein, not counting SEPTA holidays. In the case of pre-revenue service tests per 49 CFR 238.111 (b) (2), 45 calendar days notice shall be given to the Engineer in order to assure timely notification of the FRA.

SEPTA reserves the right to make, upon request, at its own expense, additional operating tests of each locomotive separately to verify the acceptability of the locomotives. These additional tests will be conducted within 30 days after completion of Contractor acceptance testing, prior to SEPTA's acceptance of the locomotives. The Contractor may be required to participate in and furnish technical assistance for such tests. It will be compensated for such participation and assistance as can be shown to be extraordinary, unless the result of the testing indicates that the vehicle was non-compliant with the Technical Specification (in line with the stated purpose of the testing), in which case the entire expense of the Contractor’s participation and technical assistance shall be borne by the Contractor.

The Engineer, at its own discretion, can allow the Contractor to furnish test results/reports which indicate that equipment furnished under this Contract is identical to equipment which has been previously tested and accepted for the same application by a domestic United States passenger railroad. Such results shall indicate that the equipment is identical to that supplied for the SEPTA program and that conformance with all requirements of this Technical Specification are met. If the substituted results are not approved by SEPTA, the required tests shall be performed as specified. Production conformance and locomotive commissioning tests shall be performed regardless of acceptance of substitute proof of design tests by SEPTA.
16.4 TEST PLANS AND REPORTS

16.4.1 Test Plans

The Contractor shall provide a Master Test Plan listing all tests to be performed to SEPTA for review and approval. The test plan shall be provided within 90 days from Notice to Proceed, and revised within 30 days of any change in plans.

The Contractor shall submit to the Engineer for approval a Master Test Plan covering all tests and adjustments listed in or otherwise required by this Technical Specification. The Master Test Plan shall include, and differentiate between, the Engineering Tests, Production Conformance Tests, and Locomotive Acceptance Commissioning Tests. The frequency and proposed schedule for each test shall also be included. The Master Test Plan shall be submitted to the FRA to comply with 49 CFR 238.111.

The Test Plan shall cover all supplier and subcontractor tests to be completed at their plants, all Contractor tests to be completed at its plant prior to issuance by the Engineer of a Release for Shipment document and all testing to be conducted on SEPTA property prior to issuance by the Engineer of a Certificate of Acceptance.

The Inspection Plan and the Master Test Plan shall be administered by the Contractor’s Quality Assurance Department. It shall be the responsibility of the Quality Assurance Department to ensure that all inspection and test requirements have been met, inspection and test data is complete and accurate, any follow-up or corrective action that may be required has been completed, and all final reports are complete, accurate, and Specification compliant.

The Contractor’s Quality Assurance representatives shall perform inspections at subcontractor and supplier facilities to ensure compliance with all aspects of this Specification.

The Contractor shall maintain a History Book, as defined in Section 1.18. The History Book shall be submitted to SEPTA for review before each vehicle shall be released to the Commissioning site. The History Book shall include all Contractor and SEPTA in-process and final inspection sheets and test data records for each vehicle.

The Contractor shall test vehicle functions and performance to assure compliance with all technical requirements. Functional tests shall be performed to approved procedures. The results shall be documented and included in the History Book. Final vehicle inspection shall not be permitted until functional testing is completed and successful.

A test log shall be maintained during equipment assembly. The log shall be submitted to SEPTA for review before each locomotive shall be released for shipment to the commissioning site.

16.4.2 Test Procedure

The Contractor shall prepare a detailed Test Procedure for each test described herein, and for any other tests conducted by the Contractor in connection with its own quality assurance program. Each test shall be a separately controlled document and identified by its own number, title and revision. All revisions
shall be submitted to the Engineer for approval. A history of test revisions and changes shall be maintained and recorded within the test document. All tests must be written in an instructional form describing the full activity of each test step, and written in duplex-numerical form (similar numbering system as seen in this specification). All special tools and/or equipment to be used must be specified within the test document. A data collection form shall be used with each procedure and shall be fully identified.

The Contractor shall develop test procedures which shall provide detailed instructions for the conduct of tests and documentation of results including Pass/Fail criteria. The test procedures shall identify all settings and calibrations. Test procedures shall be delivered to SEPTA for approval at least 90 days prior to the test date. SEPTA shall retain the right to attend any or all of the tests.

Each individual test shall be accompanied by a separate test results sheet. Each step of the test requiring a specified result or measurement shall be included and identified by the duplex-numeric step number referenced in the test document. Areas shall be provided for recording actual values produced during the test where needed. In addition, acceptance criteria and associated tolerances shall also be shown in parenthesis near the space available for recording the actual value. Each test sheet shall be identified by the associated test number and revision. Areas shall also be allocated for the date, locomotive number, component serial numbers (as applicable), test equipment serial numbers, verification of test equipment calibration, test status (accept/reject) and signature areas for the test technician, Contractor QC and SEPTA Field Representative.

When test results indicate failure to comply with Specification and acceptance requirements, equipment rework shall be performed, followed by subsequent retest, until compliance with the stated requirements is achieved.

To be considered that all test requirements have been met, each individual test must demonstrate that the entire set of prescribed criteria has been met at that time. If a test fails to do so, then the individual test shall be rerun in its entirety. SEPTA may, at its discretion, waive portions of the rerun test.

16.4.2.1 Testing Notification

In the case of pre-revenue service tests per 49 CFR 238.111 (b) (2), 45 calendar days notice shall be given to the Engineer in order to assure timely notification of the FRA. For other tests, each detailed Test Procedure shall be submitted to the Engineer for review far enough in advance of the planned test date to allow the Engineer at least 15 working days to initially review and comment on, or approve the procedure, and still have sufficient time to allow the Contractor to modify a rejected procedure and resubmit to the Engineer, to have approval a minimum of 3 working days prior to any testing covered by the procedure. The Engineer will, at its option, witness all tests.

Upon the completion of each test, the Contractor shall submit a written report of each test, including copies of all test data, to the Engineer for approval. In every case, the report shall include a description of the test, all raw data collected in the test, and a summary of the results in a form that can be directly compared to the Technical Specification without further calculations. A test shall not be considered as completed until the Engineer (and the FRA, as required) has approved its final written test report.
Should the Test Procedure or Reports be inadequate and not meet the requirements of the Technical Specification of the FRA, the Engineer reserves the right to require additional plans, procedures, details, and schedules to satisfy itself that the test program or report is adequate and does meet FRA and Specification requirements. The approval of the Engineer does not in any way relieve the Contractor of responsibility for the adequacy of the Test Program within the scope of this Technical Specification.

16.4.2.2 Test Documentation

The Contractor shall develop test reports which describe test results and present supporting data. Engineering/Proof-of Design test reports must be submitted within 7 days of completion of the test. The Contractor’s Quality Control Department shall certify all test results prior to submission to SEPTA.

Test reports shall be submitted for each test required by the approved test plan. The test reports shall contain, as a minimum:

- Part number of equipment tested;
- Serial number(s) of equipment tested;
- Identity of test conducted;
- Specification Section reference;
- Date of test;
- Identity of person(s) conducting test;
- Identity of witnesses and/or inspector;
- Pass/Fail criteria;
- Summary of test results;
- Copy of data recorded; including Plots, graphs, charts, schematics and photos that support conclusions.
- List of any discrepancies, deviations or exceptions.
- Calibration certificates for all test equipment used.
- Test location.

Test reports for tests completed prior to shipping of equipment to the Contractor shall be submitted to SEPTA at or before time of shipment of the equipment to the Contractor's facility.

Upon the completion of all required Engineering Tests associated with the Pilot Locomotive program, all copies of all test procedures, reports and approvals shall be copied and presented to the Engineer in a
single volume. In the case of tests which are performed on all locomotives, or on all components, a separate volume shall be submitted to the Engineer containing all approved tests applicable to individual locomotives. In the event a test is revised, the Contractor shall supply a copy of the test reflecting approved changes and the upgraded revision status to replace the existing test within this volume. Test Result sheets of tests performed on individual locomotives shall be included in the appropriate Locomotive History Book.

Test reports for tests completed prior to shipping of equipment to the Contractor shall be submitted to SEPTA at or before time of shipment of the equipment to the Contractor's facility.

16.4.2.3 Testing and Rework

When test results indicate failure to comply with Specification and acceptance requirements, equipment rework shall be performed, followed by subsequent retest, until compliance with the stated requirements is achieved.

To be considered that all test requirements have been met, each individual test must demonstrate that the entire set of prescribed criteria has been met at that time. If a test fails to do so, then the individual test shall be rerun in its entirety. SEPTA may, at its discretion, waive portions of the rerun test.

16.4.3 Locomotive Acceptance Testing Facilities

For an acceptance test site facility, the Contractor will be allowed by SEPTA to use a portion of the yard tracks and the automotive parking lot at SEPTA's Frazer Electric Locomotive Shop. The Contractor will be responsible for providing office trailers for its use, and for arranging for electricity and telephone service at its expense. The Contractor shall use this site to prepare locomotives for acceptance testing, and to perform modification or rework required on locomotives under its control prior to acceptance, as well as warranty work. SEPTA will supply, at no charge to the Contractor, the catenary power, tracks, train crews and supervisors as required to operate the locomotives on the SEPTA Railroad Division and for yard movement of locomotives. SEPTA will designate the hours (during off-peak and late evening periods, in general) that its tracks will be available for testing and assign crews as requested by the Contractor, who shall give a minimum of 24 hours notice of crew and track requirements to the Engineer. Emergency operating conditions must take priority, however, over the Contractor's request for usage on rare occasions. Note that all locomotive and train operations must take place under the regulations of the FRA, the Northeast Operating Rules Advisory Committee (NORAC) operating rules, and SEPTA Railroad Division rules.

16.4.4 Engineering Tests

This Section relates to the Pilot Locomotive and Pilot Train which shall be tested and shall meet all Specification Conformance and train test requirements. Engineering tests shall be scheduled as Pre-production (Section 20.6), Pre-delivery (Section 16.5), On-site functional (Section 16.7) and Operational (Section 16.8 through 16.10) testing. In addition, a first article inspection must be performed for every major component of the locomotive as well as for the first locomotive, in accordance with Section 1.11.9.12. Components and locomotives shall pass each test in acceptable condition.
16.5 ENGINEERING PRE-PRODUCTION TESTING

16.5.1 General

The pre-production tests are a "proof of design" test and are those qualification and type tests conducted to ensure equipment meets the functional and performance requirements of the specification. All components, subsystems, systems, and vehicles supplied under this Contract and as listed below shall be given a Proof-of-Design test to determine conformance to the requirements of this Specification and any performance criteria identified during the design review phase. These tests are typically conducted on at least one (in some cases several) example of each component comprising the first locomotive produced. They do not have to be repeated for identical components to be used in the other production locomotives.

### Engineering Pre-production Testing

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### 16.5.2 Frequency and Application

Frequency and application are individually defined for each test. While subsystem and system tests are typically conducted by the equipment manufacturer, the Contractor is ultimately responsible for all tests.

### 16.5.3 Material Certifications

All materials used in Locomotive construction shall be tested to verify compliance with the physical properties requirements in Section 15 as appropriate for each item. Seats shall be tested for compliance with Section 5.

### 16.5.4 Glazing Tests

Two samples of all glazing material shall be tested in accordance with Sections 15.2 and 4.7, including windshield heating requirements, as applicable.

### 16.5.5 Smoke and Flammability Tests

All carbody interior materials shall be tested in accordance with Section 15.8 for compliance by an independent laboratory.

### 16.5.6 Couplers and Draft Gear

The complete coupler assembly shall be tested to validate conformance to the requirements of Sections 3.9, including all FRA regulations and AAR standards and recommended practices.

Coupler and draft gear Proof-of-Design test shall include the following tests to verify compliance with the requirements of Section 3.9:

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• Coupler draft and buff loading;
• Draft gear deflection;
• Anchor casting static loading;
• Gathering range, and mechanical coupling and uncoupling;
• Centering;
• Vertical strength.

The mechanical coupler, as well as, the pneumatic hoses and electric cables shall be subjected to 100,000 cycles of coupling and uncoupling.

16.5.7 Coupler Leads and Inter-car Jumpers

16.5.7.1 General

The coupler leads and inter-locomotive jumper supplier shall conduct the following tests to demonstrate compliance with Section 2.2.13, inclusive, for any new cables not carried in existing SEPTA inventory.

16.5.7.2 Life Test

The coupler leads and inter-locomotive jumper cables shall be mocked-up as installed and supported on the vehicle or between vehicles and given a 100,000 cycle flexing test equivalent to the motions the cables would see with the locomotive negotiating the "worst case" conditions for vertical and horizontal curves and minimum turnout. The electric coupler cables shall be electrically energized during this test, with signal levels representing the full range of those that would normally be experienced in service. The pneumatic hoses and couplings shall be pressurized. There shall be no failure to mechanically, pneumatically and electrically couple or uncouple. There shall be no electric cable contact failures, no loss of continuity of any signal during testing, and the spring forces shall not diminish.

After the application of the 100,000 cycles of flexing, the leads and cables shall exhibit no evidence of wear or failure. At the conclusion of the test, the cables shall exhibit no evidence of short circuits, open circuits, intermittent circuits, high resistance circuits, insulation wear or failure, or broken wire strands, as verified by disassembly and inspection and dielectric tests. No insulation wear or rupture shall be permitted and no wire strands may be broken.

The Contractor shall provide written assurance, not later than 1 month after selection of the coupler leads and jumper cables supplier but in any case not later than 6 months after Date of Award, that the subject supplier understands this requirement and is capable of conducting the test.
16.5.7.3 Electrical Test

The coupler leads and inter-locomotive jumper cables shall be tested at the manufacturer's facility to verify correct pin-to-pin continuity and to ensure that the wiring insulation requirements of Sections 15.22 and 15.23 are met. The wiring insulation test shall be performed before and after the life test defined in the preceding paragraph.

16.5.8 Traction Motor and HEP Inverters

The inverter Proof-of-Design test(s) shall be designed and performed to demonstrate compliance with the requirements of Sections 8.0 and 9.0, as applicable, including all aspects of the following for the environmental ranges and supply voltages given in Section 2.2.8.1, as applicable.

- All output and control requirements;
- Performance and capacity requirements;
- Fault detection and annunciation requirements;
- Insulation, isolation, and transient rejection requirements;
- Heat run, designed to test the system for the worst case heat loadings; as follows:
  - Maximum rated output current at the lowest operational input voltage;
  - Lightest possible load, at the highest operational input voltage.

The first complete set of HEP inverters produced shall be given a "type" test by the manufacturer as defined by IEEE Standard number 16 to the applicable standards contained therein as a minimum, including a heat run at both nominal and minimum voltage. In addition, an integrated system test shall be conducted. This shall completely duplicate the locomotive loads, including the startup currents of inductive loads such as the air compressor motor. All operating conditions, including intermittent power collector contact, shall be simulated. Environmental electrical extremes shall be included such that all protective and regulating features are exercised by appropriate manipulation of test voltages and loads. Equivalent loads for that of the actual locomotive equipment may be used.

The inverter Proof-of-Design test may be incorporated into the propulsion prototype test and shall be performed at the manufacturer's facility on a prototype inverter unit.

16.5.9 HEP System

The HEP system supplier shall provide step load resistance tests to cover the full load range at his facility prior to installation on the first vehicle. This network shall use as a minimum incremental step loads of 10% to 90% and 90% to 10%.
This test shall verify system function and performance for the environmental ranges and supply voltages given in Section 8.

### 16.5.10 AC Motors

The first motor of each type and one of each type selected at random by SEPTA shall be tested by the manufacturer to verify compliance with the manufacturer's design requirements, Section 15.25.11, and the appropriate section for the specific application. The manufacturer shall also perform an IEEE "type" test in accordance with IEEE 112A for the electrical characteristics and IEEE 11 for the mechanical characteristics, including a heat run, to demonstrate its capabilities and power rating. Impulse and surge comparator tests, or equivalent, shall be included. The determination of the characteristics and efficiency of the traction motor shall be in accordance with a mutually acceptable method from IEEE-112, adapted to include testing at minimum frequency, base speed, maximum slip-limited speed and maximum speed.

The motors shall be operated at the same voltage, frequency and current as used when installed. Commercial industrial motors which do not have type test data available from the motor manufacturer shall either be certified by the manufacturer for use on an inverter power supply of the exact characteristics found on the locomotive, or shall have a type test conducted using such a power source. In the case of the traction motors, the first motor shall be given a "type" test. Alternative testing plans may be submitted to the Engineer for approval.

### 16.5.11 Battery and Battery Charging System

Battery capacity and the low voltage system charging network shall be tested to verify their compliance with the requirements of Sections 8.0 and 9.0.

Tests of battery capacity and of the low voltage power supply per Section 8 shall be made to show compliance with their requirements. The ability of the LVPS to charge the battery and support other low voltage loads shall be verified. The capacity of the battery to support essential loads for the required time upon loss of LVPS output shall also be verified. The ability to check the battery fluid levels and refilling shall be demonstrated.

### 16.5.12 Reactors

One of each type reactor shall be tested to IEEE Standards 1, 3, 4, 11, 16, 118, 119, and 120. In addition to the IEEE tests, each reactor shall receive the following:

- Incremental inductance test.
- Four Minute heat run on 60 Hz rectified A.C.
- Continuous heat run on 60 Hz rectified A.C.
- Ripple value measurements at 80% of rated load.
- Commutation performance test with traction motor.

**16.5.13 Water-tightness**

In addition to the water-tightness test specified for all vehicles in Section 16.9.3, the following tests shall be conducted on the first vehicle of each type as part of the Proof-of-Design test:

**16.5.13.1 Ducts**

The fresh air and electric equipment ventilation intake ducts shall be water tested with the ventilating fans running at full speed to determine the effectiveness of the water-excluding features of the ductwork.

**16.5.13.2 Equipment Boxes**

All equipment boxes shall be water tested by the equipment manufacturer during the FAI of the equipment, when appropriate.

**16.5.13.3 Traction Motor Leads**

The traction motor lead connections shall also be given a water tightness test. The water flow rate and velocity employed for this test shall be as specified in Section 16.9.3 for the locomotive body water test.

**16.5.14 HVAC System**

**16.5.14.1 General**

One air conditioning system and its complete controls shall be given a qualification and capacity test by the air conditioning manufacturer to verify the proper functioning of the system. This test shall be successfully completed before fabrication into the locomotive. Test shall be conducted in accordance with ANSI/ASHRAE Standard 37 by an independent or manufacturer's laboratory, approved by SEPTA. The actual HVAC control system with actual thermistors and pressure transducers shall control simulated system operations during the test, unless indicated otherwise for specific tests.

Tests shall be conducted at nominal voltage, except where otherwise specified. Appropriate test log sheets and calculation forms shall be generated and included with the test procedure for approval. They shall become a part of the test report.

The accuracy and tolerances of all instrumentation and tests shall comply with the requirements of Section 9.2 and Table 4 of the ASHRAE Standard 37. Temperature measurements and measurement techniques shall comply with ASHRAE Standard 41.1. Proof of all instruments calibration, traceable to a master at the National Institute of Standards and Technology (NIST) or similar standards organization of the applicable country, shall be approved by SEPTA prior to commencing of the tests.
All data required by ASHRAE Standard 37 shall be continuously recorded by the approved data acquisition system with appropriate calibrated transducers.

### 16.5.14.2 Temperature Control Tests

The HVAC system shall be functionally tested. Controls and dampers shall be checked to ensure proper operation and circulation of air and even temperature distribution throughout the cab.

### 16.5.14.3 Air Conditioning Tests

The following tests of the air conditioning system shall be conducted:

#### 16.5.14.3.1 Cooling Capacity

Cooling capacity shall be demonstrated by tests performed in accordance with ANSI/ASRAE Standard 37-2005.

#### 16.5.14.3.2 Maximum Operating Conditions

Maximum Operating Conditions functional tests shall be conducted at the same design load as the capacity test above except with the ambient dry bulb temperature at 115°F. Corresponding wet bulb temperatures shall be as necessary to provide the same humidity ratio as at the design conditions. The system shall continuously operate at its full capacity for at least one hour at each of these conditions without shutdown due to high pressure, circuit breaker trip, motor overload, or any other device actuation or failure. Data required by the ANSI/ASHRAE Standard 37 shall be recorded at five minutes intervals. At the end of one hour of operation at each of the above conditions, the system shall be momentarily stopped, then restarted, and shall continue to operate properly without any malfunction. The test shall be conducted at nominal, low, and high voltage specified limits.

### 16.5.14.4 Heating Tests

The following tests of the heating system shall be conducted.

#### 16.5.14.4.1 Heating Capacity

The heating capacity of the heaters shall be verified by measuring electric characteristics of the heaters.

#### 16.5.14.4.2 Abnormal Heating Condition, Restricted Air

An abnormal heating condition, restricted air test shall be conducted at approximately 70°F with the heaters activated independently of the thermostat and with any air flow detection device bypassed. The test shall be conducted by slowly restricting the mixed air inlet so that heater unit temperature rise does not exceed 2°F per minute, until the over temperature protection system turns the heating off. The restriction shall then be eased until the protection system resets. The heating test shall continue, to simulate a dirty filter condition. The system shall operate until a steady state is reached and minimum of
30 minutes thereafter. Temperature readings shall be recorded every five minutes. The test shall be conducted at nominal, low, and high supply voltage specified limits. The test criteria shall be as follows:

- The over temperature protection system does not activate during the test.
- The temperatures inside the unit does not cause damage to the equipment and components.
- There is no smoke or odor.
- The over temperature protection system activates and deactivates at the design set point ±10°F.

16.5.14.4.3 Abnormal Heating Condition, No Air

An abnormal heating condition, no air test shall be conducted at approximately 70°F on each of the forced air heating units. The over temperature protection system shall be bypassed. Power shall be applied to the heaters with no air blowing over the heaters. The system shall operate as the over temperature protection system cycles the heaters.

The criteria of the above test with restricted air shall apply for this test. The test shall be conducted at nominal, low, and high voltage specified limits.

16.5.14.4.4 Back-up Shunt Trip Circuit Breaker Protection

A back-up shunt trip circuit breaker protection test shall be conducted at approximately 70°F on each of the forced air heating units. Prior to power application to the heaters, the over temperature protection system shall be bypassed. The heaters shall be energized and the shunt trip activation temperature shall be observed. The equipment interior temperatures shall be recorded from the start of the test throughout a 30-minute period following opening of the shunt trip circuit breaker. The test shall be conducted at nominal, low, and high supply voltage specified limits. The test pass criteria shall be as follows:

- The temperature inside the unit does not cause any damage to wiring, electrical components, motor, and unit insulation.
- There is no smoke or odor.

16.5.14.4.5 Back-up Shunt Trip Circuit Breaker Protection Overshoot

The heating systems shall each be operated in the full heating mode at the high supply voltage specified limit for a minimum of one hour. At the end of the hour, the heater and blower shall be simultaneously shut down. The residual heat temperature rise shall not cause a nuisance actuation of the shunt trip circuit breaker.
16.5.15 Propulsion Prototype Test

A laboratory test shall be conducted on a complete set of prototype propulsion, dynamic braking and friction brake control equipment as specified in Section 11, prior to beginning production of that equipment, using a dynamometer which simulates vehicle inertia by means of flywheels and/or programming of a motor generator, and which simulates train resistance by means of a motor generator. Friction brake equipment shall consist of all valving necessary to demonstrate blending, spin-slide and all other controlled functions. This test is for the purpose of demonstrating that this equipment functions properly and meets all requirements of Section 2.0, simulating typical operation of SEPTA’s push-pull fleet, or by performance over a derived sequence which can be shown to produce the equivalent duty cycle. The test shall simulate all ordinary and extraordinary operations and environmental conditions so that all protective and operational features of the equipment and its controls, particularly the logic software, are completely exercised. The parameters and responses of the inverter and motors may be simulated such that all control loops are realistically closed.

Preliminary EMI testing shall be performed on the prototype laboratory equipment, for conductive and inductive emissions, as referenced in Section 2.6.

16.5.16 Friction Brake

Successful completion of Sections 16.5.16.1 through 16.5.16.3 and the locomotive performance tests of Section 16.7.1 and acceptance of the test results by SEPTA shall be required for final approval of the friction brake system.

16.5.16.1 Brake Unit Fatigue Tests

16.5.16.1.1 Test Description

A test setup shall be arranged such that one tread brake unit and one disc brake assembly are exposed to simulated conditions they shall encounter in service, including shoe force and force developed by braking torque in each direction. The brake pad and shoe shall be loaded by applying air pressure equivalent to a maximum service brake (friction only) application to the disc brake assembly and the tread brake unit, and the forces developed by brake reaction torque shall be applied through the mounting arrangement. The brake assemblies shall be placed in an environmental chamber capable of imposing the minimum and maximum specified operating temperatures and airborne dirt and moisture according to a cycling schedule, approved by SEPTA, throughout the duration of the test. The direction of the reaction torque shall be reversed every ten brake applications. They shall be subjected to 1,000,000 cycles of the full friction working loads predicted. The load levels shall be approved by SEPTA.

16.5.16.1.2 Test Criteria

The brake assemblies shall be considered acceptable if no component failure of any kind or any abnormal wear occurred during the 1,000,000 consecutive operating cycles. A complete teardown inspection shall be conducted following the test to verify full compliance.
16.5.16.2 Brake System Endurance Test

16.5.16.2.1 Test Description
The first complete production friction brake system shall be assembled before mounting on a vehicle and shall be subjected to an endurance test of 250,000 cycles of normal applications and releases to demonstrate that the control apparatus has the endurance required for intended rail service. For each cycle, the Brake Control Unit shall 1) apply, 2) hold (with controlled leakage) and 3) release in response to reductions and increases in brake pipe pressure. The wheel slide control valves shall be tested for 1,000,000 cycles of modulating application and release according to an approved routine. The system shall be tested in an environmental chamber and subject to an approved cycling schedule of simulated conditions.

16.5.16.2.2 Test Criteria
The system shall be considered acceptable if no component failure of any kind or any abnormal wear occurred during the specified consecutive operating cycles. A complete teardown inspection shall be conducted following the test to verify full compliance.

16.5.16.3 Braking System Capacity Test

16.5.16.3.1 Scope
A full scale dynamometer test shall be performed to demonstrate that the proposed foundation friction brake components shall perform as required and that thermal capacity requirements have been met.

16.5.16.3.2 Test Conditions
The dynamometer test shall consist of the procedures listed below as a minimum requirement. The test conditions for each procedure are detailed after the description of each procedure.

Tread brake actuators and disc brake calipers shall be the same model to be employed on the locomotive. Prior to the test, static shoe force and/or pad force measurements shall be made at all brake cylinder pressures in 10 psi increments.

Test wheel diameter shall be 36 inch nominal and shall be curved plate, multiple wear, with tread surface material machined away to simulate fully worn conditions. Dynamometer speeds shall be adjusted for worn wheel diameters.

Test criteria for the locomotive shall include static axle load, allowance for rotational inertia, a fully loaded consist (seated capacity) and 15% inoperative brakes on the consist.

Brake cylinder pressure build-up rates shall comply with the specified maximums in Section 2.2.7.3 and shall match the actual locomotive build-up rate within ±0.25 seconds for both full service and emergency.
Maximum allowable measured temperatures permitted during any of the following tests are 600°F for wheel tread, and the maximum allowable temperature recommended by brake disc manufacturer for the brake disc.

Maximum allowable stop distances shall comply with Section 2.2.7.3.

16.5.16.3.3 Stop Distance Tests

The following procedure shall consist of a series of stops made from initial speeds of 60, 100, 40, 125, and 80 mph, in that order. Two sequences shall be considered a series. One series shall be run using full service net shoe force and pad force and another series shall be run using emergency net shoe force and pad force. The wheel and disc is to air cooled between stops to a maximum temperature of 80°F. (above ambient) All shoes and pads shall be worn-in to achieve at least 85% bearing surface contact.

1. Wear-In Procedure
   The wear-in procedure shall consist of a minimum of 20 stops from an initial velocity of 70 mph. The brake shoe forces shall not exceed a full service brake application. Additional stops may be performed as required in order to achieve the minimum bearing area. The maximum initial temperature at the beginning of each stop shall not exceed 80°F. (above ambient)

Stop Distance Test Data Requirements

The following data shall be recorded:

- Gross Stop Distance (GSD) in feet.
- Time for each stop in seconds.

The actual initial velocity (Vi) in miles per hour.

NOTE: Time and distance shall be measured from the point of initiation (manual or automated beginning of brake cylinder pressure build up. Data recording equipment time delays, if any, shall be accounted for). The dynamometer facility shall also record and report any dead time for each stop between point of initiation of the brake application and the beginning of brake cylinder pressure build up, if any, and the amount of time required to reach 95% of the target brake cylinder pressure for each brake application.

Full net shoe force (NSF) at full service brake cylinder pressure, in pounds force, including build-up rate vs. time for full service and emergency brake application.

NOTE: A static shoe force (refers generically to both on-tread shoe force and disc caliper pad force) measuring device may be used for determining NSF. It shall be shown, however, that the dynamic shoe force component normal to the wheel tread or disc friction ring is within
+5% of the measured static shoe force. If the static shoe force does not fall within these limits, the dynamic shoe force (normal component) shall be recorded.

Actual Equivalent Wheel Load (EWL).

Continuous temperature vs. speed from Vi to stop.

NOTE: Continuous air flow from fans or blowers shall be directed from one direction to both sides of the disc and wheel. A minimum of two thermo-couples shall be provided for measuring disc surface temperature (one each side of the disc) and at least one shall be provided for measuring wheel tread surface temperature. The thermo-couples shall be located on a line intersecting the center of the friction material center, 900 past the trailing side of the friction material center.

Continuous brake torque, in foot pounds vs. speed from Vi to stop.

Continuous coefficient of friction vs. speed from Vi to stop. This value is to be provided for disc-only or tread-only configurations.

A curve showing initial velocity (Vi) vs. gross stop distance (GSD) for each series of stops. Separate curves shall be generated for full service and emergency.

NOTE: Each curve for Items 4, 6, 7, 8, and 9 above shall be printed on grid paper with sufficient divisions to interpolate values within two significant figures.

16.5.16.3.4 Slowdowns

A series of slow downs from 125 mph to 90 mph using full service net shoe and pad force with two (2) minutes between brake applications shall be run. After each slowdown brakes shall be released upon reaching 90 mph and the dynamometer shall accelerate immediately, at the specified performance rate, up 125 mph. A test cycle consists of six slowdowns and a test series consists of two test cycles. Wheel and disc are to be air cooled to a maximum of 60°F (above ambient) between cycles. Temperatures, as measured according to the stop distance test arrangement, shall not exceed specified maximums.

16.5.16.3.5 Northeast Corridor Profile

A simulated Northeast Corridor profile, from Newark, DE to Trenton, NJ, shall be run on the dynamometer test set-up. The speed/time profile shall be provided by SEPTA. All brake applications shall be full service. The following data is to be recorded and a graph generated:

1. Maximum wheel and disc temperature for each brake application, and temperature immediately prior to brake application. Temperature measurements shall be taken as described in the stop distance tests. The graph shall plot temperature change vs. brake application number and maximum temperature vs. brake application number.

2. Vi/T versus brake application.
3. Shoe and pad wear for each run.

4. Actual distance run.

5. Average coefficient of friction from initial to final speed.

16.5.16.3.6 Glazing Test

A series of applications equivalent to a snow brake application shall be performed. Each application shall be held for 2 minutes followed by release for one minute. A series of 12 applications shall be made. At the end of this test the pads and shoes shall be removed from the dynamometer and inspected. No evidence of glazing is permitted. If small amounts of glazing are found, then the pad and shoe shall be reapplied and the test repeated. No additional glazing is permitted.

16.5.16.3.7 Wet Stop Distance Test

A repeat of the stop distance test procedure given in Section 16.5.16.3.3 shall be performed with water spray applied to the disc and wheel at the pad/disc and shoe/wheel interface. The water spray pattern and flow rate shall conform to the pertinent UIC sub-section 54 test procedure. Gross stop distance may not increase by more than 15% nor decrease by more than 10%.

16.5.16.4 Air Storage Capacity

The Contractor shall conduct a test to demonstrate that the storage capacity of the air system complies with the requirements of Section 12.4.7.

16.5.16.5 Air Compressor Capacity Test

The first production air compressor/drier system shall be capacity tested in accordance with ASME PTC 10. The test shall also include operation at simulated minimum duty, design duty, and worst case duty air usage cycles; minimum, design, and maximum motor input voltage and minimum, nominal, and maximum temperature and humidity conditions according to an SEPTA approved plan. A minimum ambient temperature motor start test shall be included. Air output quality shall be continuously monitored throughout all testing.

16.5.17 Truck Tests

One truck shall be subjected to the following tests. Upon satisfactory completion of the tests, a report with all results, calibrations and stress levels shall be completed and provided to SEPTA prior to assembly of the first truck into a locomotive.

The first locomotive shall be used in the performance of the Equalization Test and the Stability Test.

16.5.17.1 General

The first locomotive shall be used in the performance of the Equalization Test and the Stability Test.
The first truck frame and bolster shall be subject to the following static and fatigue tests to verify that the maximum allowable stresses, specified in TS 11.12.1 are not exceeded. The first production truck shall be used unless otherwise specifically approved by SEPTA. Prior to the test, a magnetic particle and dye penetrant inspection of the truck for cracks shall be performed in the presence of SEPTA. If the allowable stress is exceeded, or cracks are detected, the design shall be corrected and reinspected before testing.

Not less than one hundred (100) strain gauges shall be applied to the truck at locations as agreed to by the Contractor and SEPTA, SEPTA having the power of decision in the event of a disagreement. All gauges shall be monitored for the static and overloads tests of TS 11.15.2, and TS 11.15.3. Selected gauges shall be monitored throughout the fatigue test of TS 11.15.4. The locations to be strain gauged shall be determined by analysis and by a preliminary static test to determine the location and direction of stresses using analog methods such as brittle lacquer or photo elastic methods. If the Contractor elects to use analytical methods instead of analog methods, then the Contractor shall apply not less than 100 rosette strain gauges to the truck at locations of expected high stress and areas of interest as agreed to by the Contractor and SEPTA. Manual calculations may be required in areas of high stress gradient or near welds to extrapolate the test results to determine the critical stresses. SEPTA shall determine the locations in the event of a disagreement. There shall be no less than two (2) locations where there are a sufficient number of gauges to encircle the side frames, and two (2) locations that encircle the bolster, to appraise the stress distribution at these cross sections.

Dial indicators or other deflection gauges shall be arranged to monitor lateral and vertical deflections at the primary suspension interface, at the truck side member mid-spans, and the vertical deflection of the truck center. These indicators shall be monitored for the static and overloads tests of TS 11.15.2 and TS 11.15.3.

The Contractor is responsible for determining appropriate test loads and conditions that shall illustrate the adequacy of the truck design to meet SEPTA’s requirements. Test loads and conditions specified herein are minimums. The Contractor may impose greater test loads and more severe test conditions.

Prior to the tests, the Contractor shall provide a drawing showing any defects that existed in the truck elements as produced, and the repairs made to the parts containing these defects.

16.5.17.2 Truck Static Test

16.5.17.2.1 Test Description

The purpose of this test is to verify that the maximum allowable stresses specified in Section 10.12.1 are not exceeded. This is a static load test, repeated twice, with complete release between applications. The test shall be performed with the suspension elements replaced by solid blocking with an approved elastomeric material between solid blocking and truck frame to minimize changes in load application due to truck frame deflection. The truck shall be tested either by individual load bearing components of the truck or as an assembly, as approved. If the load bearing components of the truck, rather than the complete assembly, are tested, provision shall be made to apply all input loads described herein and for the member under test to react to these input loads in a manner which is identical to the reactions that
would occur when included as part of the assembly. Forces shall enter the parts or truck at the normal application points, and shall be so combined in each case as to produce the maximum unit stresses at the critical points for which the stress estimates were furnished. The stress readings for the two applications shall be averaged for comparison with the estimated stresses. The tests shall be witnessed by the Engineer.

The vertical load shall be 55% of the fully loaded body shell weight. The lateral load shall be the load at overturning, and the longitudinal load shall be 15% of the vertical load. The lateral and longitudinal loads shall act as if applied at the center of gravity of the fully loaded locomotive body. Accessory loads, such as disc and tread brake units and traction motors, shall represent maximum motor torque (including fault condition torque) and brake unit weight, and maximum brake unit reaction and motor weight. If the anticipated harmonic dynamic reaction (as at the motor nose suspension point) exceeds this steady state value, the greater reaction shall be applied. All loads shall be applied simultaneously.

<table>
<thead>
<tr>
<th>Tread Brake Unit (TBU)</th>
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<tbody>
<tr>
<td>Horizontal</td>
<td>Max Outward Reaction</td>
</tr>
<tr>
<td>Vertical</td>
<td>Max Vertical Reaction plus six (6) times the TBU weight</td>
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</tbody>
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<table>
<thead>
<tr>
<th>Disc Brake Unit (DBU)</th>
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</thead>
<tbody>
<tr>
<td>Horizontal</td>
<td>Max Horizontal Reaction</td>
</tr>
<tr>
<td>Vertical</td>
<td>Max Vertical Reaction plus six (6) times the DBU weight</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Motor and Gear Box</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Horizontal</td>
<td>Reaction from maximum steady state torque</td>
</tr>
<tr>
<td>Vertical</td>
<td>Reaction from maximum steady state torque plus five (5) times the weight supported by the truck frame</td>
</tr>
</tbody>
</table>

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<tr>
<th>Dampers</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Horizontal and Vertical</td>
<td>Peak force from damper at maximum operating velocity</td>
</tr>
</tbody>
</table>

The stress results of the two (2) load applications shall be compared with the calculated stresses, and the higher shall be less than the allowable stresses, as specified in TS 11.12.1 for all gauges. If the stress exceeds the allowable stresses, the truck design shall be corrected to bring the test stress to less than the allowable stress. The redesigned truck shall be retested at the expense of the Contractor, and all trucks previously constructed shall be modified to be in accordance with the corrected design.

A static test of the fatigue combination loads in TS 11.15.4 shall be conducted and the results presented as part of the static load test report. Additionally, the results shall be compared with the corresponding stress analysis results. Comparisons shall be made for all gauges in areas sufficiently away from changes in section to ensure that the load is being carried through the expected load paths, but not less than half of the total number. This shall include the gauges encircling the side frames and bolster, as well as other gauges of interest selected jointly by the Contractor and SEPTA, with SEPTA determining the locations in the event of a disagreement. The analysis value shall be within 20 percent of the test results. For gauges
that do not meet the requirement, a manual analysis shall be conducted, or the finite element model and analysis shall be revised as appropriate to obtain the required agreement.

16.5.17.2.2 Criteria

At no point shall the average stress exceed the allowable stress specified in Section 11.12.1. If it does, SEPTA shall require that the design be corrected to bring the test stresses within the allowable stresses; the trucks shall be retested until Specification compliant; and all trucks, including those installed under the vehicles, shall be modified or reconfigured in accordance with the corrected design.

16.5.17.3 Static Overload Test

16.5.17.3.1 Test Description

To demonstrate that the truck has adequate strength to sustain a maximum load in the presence of a combination of minor manufacturing defects, it shall be overloaded statically once with all loads applied simultaneously as follows:

<table>
<thead>
<tr>
<th>Overload Test Loads</th>
</tr>
</thead>
<tbody>
<tr>
<td>Truck Vertical</td>
</tr>
<tr>
<td>Lateral</td>
</tr>
<tr>
<td>Longitudinal</td>
</tr>
<tr>
<td>Tread Brake and Disc Brake Units</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Motor and Gear Unit</td>
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<tr>
<td>Dampers</td>
</tr>
</tbody>
</table>

Lateral and longitudinal loads shall be applied to the truck as if they were acting through the car body center of gravity. Unit stresses from all strain gauges and dimensional measurements using the dial indicators applied in TS 11.15.1 shall be taken before during and after the test. There shall be no permanent deformation as determined from dial indicator readings, and no stress shall exceed the material yield stress per TS 11.12.1

16.5.17.3.2 Test Criteria

There shall be no permanent deformation as determined from strain gauge or dial indicator readings. If such deformation appears, the design shall be corrected to bring the stress under the test condition within the elastic limit of the material involved, the truck shall be retested, and all trucks, including those installed under the vehicles, shall be modified or reconfigured in accordance with the corrected design.
16.5.17.4  Standard Fatigue Test

16.5.17.4.1  Test Description

To demonstrate that each truck type has adequate fatigue strength under dynamic loading, the truck frame and bolster shall be subjected to ten million cycles of combined loading. The loads specified are minimum values. Each test truck frame and bolster shall be tested as a unit with the suspension elements replaced by approved solid blocking.

The static vertical load shall be 110% of the ready to run car body weight on the more highly loaded truck, with the vertical fatigue load oscillating. The lateral load shall be applied first in one lateral direction and then in the opposite direction. The longitudinal load as indicated below shall be applied first forward and then rearward. Both lateral and longitudinal loads shall act as if applied at the center of gravity of the car body with resulting vertical loading, due to transferring the loads from the center of gravity to the truck. Accessory loads shall vary between plus and minus 100% of their maximum steady state values; brake unit reaction loads shall be under full service cylinder pressure with not less than 20% available adhesion.

The phasing of loads shall be kept within 15 degrees of each other, and result in maximum combined stresses at the critical locations. During the fatigue tests, selected strain gauges from the static test and all load cells shall be monitored to ensure loads are accurately applied during the test. The frequency of the load cycling shall be approximately equal to the vertical natural frequency of the truck assembly or as otherwise agreed to by SEPTA.

The truck shall be inspected regularly, but not less than every 1,000,000 cycles to detect possible crack initiation and progression. Cracks shall be defined per AAR MSRP M-213 Section 6.f Points 3 and 4. If evidence of progressive cracking or failure is found, the cause shall be assessed by SEPTA and the Contractor, after which an appropriate correction shall be established and the test repeated until successful.

<table>
<thead>
<tr>
<th>Fatigue Test Loads</th>
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<tbody>
<tr>
<td><strong>Truck</strong></td>
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<tr>
<td>Vertical (Range)</td>
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<tr>
<td>Lateral (Range)</td>
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<tr>
<td>Longitudinal (Range)</td>
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<tr>
<td><strong>Tread Brake Unit</strong></td>
</tr>
<tr>
<td>Horizontal (Range)</td>
</tr>
<tr>
<td>Vertical (Amplitude)</td>
</tr>
<tr>
<td><strong>Disc Brake Unit</strong></td>
</tr>
<tr>
<td>Horizontal (Amplitude)</td>
</tr>
<tr>
<td>Vertical (Amplitude)</td>
</tr>
<tr>
<td>------------------------------</td>
</tr>
<tr>
<td>Motor and Gear Unit</td>
</tr>
<tr>
<td>Horizontal (Range)</td>
</tr>
<tr>
<td>Vertical (Range)</td>
</tr>
<tr>
<td>Dampers (Amplitude)</td>
</tr>
</tbody>
</table>

At the conclusion of the ten million cycle fatigue test, a magnetic particle and dye penetrant inspection for cracks shall be conducted in the presence of SEPTA. If a crack is found, the design shall be corrected, the truck retested at the expense of the Contractor, and all trucks installed under the locomotives shall be modified to be in accordance with the corrected design.

Following the 10,000,000 cycle fatigue test, the frame and bolster used in that test shall be subject to additional fatigue loading, as tabulated below:

- 2,000,000 cycles with loads increased by 20% over fatigue test loads, then
- 2,000,000 cycles with loads increased by 40% over fatigue test loads

At the conclusion of the extended fatigue test, either by failure or at 14,000,000 cycles, a magnetic particle and dye penetrant inspection for cracks shall be conducted in the presence of SEPTA. If a crack is found, the nature of the crack shall be reviewed to determine if corrective action is required in the truck design.

### 16.5.17.5 Suspension

A load deflection test shall be performed to demonstrate that the spring rate of the primary suspension system in all axes are within the design limits. This test shall prove that the primary suspension system behaves as predicted and shall not result in excessive deflection or a decrease in truck clearance above top of rail to less than the minimums prescribed in Section 11.2. If defects are found, the design shall be corrected, the truck retested at the expense of the Contractor and all trucks modified to be in accordance with the corrected design.

### 16.5.18 Cab Signal, ATC and SEPTA PTC System

The Cab Signal, ATC and SEPTA PTC equipment supplier shall conduct a test at his facility on a complete Cab Signal, ATC and SEPTA PTC system to demonstrate compliance with the requirements of Section 12.0. These tests shall include complete functional tests while the equipment is subjected to the environmental and input variations specified. Equipment so tested shall conform to the manufacturing drawings. A cab signal EMI test to establish the immunity of the system to EMI shall be done.
16.5.19 Locomotive Body Structural Tests

16.5.19.1 General

The first locomotive shell shall be tested by the Contractor to prove compliance of the structure with Section 3.0. The test shall be made at the Contractor’s plant or an approved facility. The test reports shall be complete and contain sufficient detail and information for long term use as part of the permanent information to be used to maintain, repair, and modify the locomotive throughout its life.

SEPTA reserves the right to test two additional vehicles, of its own choosing, during the construction period. Should such additional tests be ordered, it shall be at SEPTA’s cost unless the tests reveal non-compliance with any applicable Specification on the part of the Contractor. If so, the Contractor shall then be responsible for all of SEPTA’s associated costs and the cost of modifications to make the vehicle and all other vehicles compliant. The tests shall be made at an SEPTA approved facility.

The bare test specimen shell shall be weighed and recorded prior to installation of any test equipment. All fixtures, dummy trucks, test equipment, tools, and test weights shall be weighed separately and recorded. The test specimen shall be completely inspected and all non-conformances corrected. All inspection, test, and corrective action reports shall be available to SEPTA for review. All test set-ups shall be reviewed and approved prior to testing. The Contractor may conduct preliminary tests, but all critical dimensions and flatness must be verified after these tests and before the official tests begin. The official test (of record) must be witnessed by SEPTA.

All gauges and instruments shall be in current calibration. The method of calibration and time period for recalibration shall be in accordance with the test laboratory’s national standard or ISO. The laboratory shall have on file a current certification of calibration traceable to the laboratory’s national standard.

Where practical, all gauges shall have an electric output suitable for recording on electronic (magnetic) media. A data acquisition system shall be provided to permanently record all gauge output at each load step. At the end of each load step, a printout of all strain gauge readings in proper engineering units (microstrains) and a plot of load vs. gauge reading for critical gauge locations shall be given to the SEPTA representative for review. The Contractor shall obtain approval from the SEPTA representative after every load step before proceeding with the next step. The Contractor shall not break down the test fixtures until the SEPTA representative has reviewed all the data.

The Contractor shall prepare a color photographic record of the test and provide to SEPTA. This record shall include photographs of the locomotive in the several test fixtures, installation of critical strain gauges, repairs or modifications, deviations from the drawings and any areas that were found to be non-compliant.

All structural tests shall be conducted on the same specimen.

The tests shall not begin until the locomotive body stress analysis has been approved.
16.5.19.1.1 Test Procedure

In addition to the requirements of Section 16.4, the test procedure shall include drawings, sketches, tables and other descriptions which provide:

- A complete description of the test load equipment;
- The exact location of each point the load is applied to the specimen;
- A table showing the load applied at each load point for each test increment;
- The exact location of each strain gauge, load and deflection measuring devices.

Annotated copies of catalogue cuts may be used to provide some of this description. An explanation of the accuracy of the instrumentation shall be provided. Drawings and sketches shall be included to clarify the text. The test procedure shall be a step by step instruction describing how load is applied, the load at each step, when to record data, and the place where authorization to proceed is to be obtained from the SEPTA representative. Test procedures shall be submitted not less than 60 days in advance of the test date, and approvals of the test procedure and stress analysis are necessary prerequisites for testing.

The test procedure shall include a copy of the current certification for every instrument and gauge to be used during the test. Typical logging sheets, print-outs, plotting forms, and examples of any other data sheets which shall be used during the test or in the final report shall be submitted as part of the test procedure.

Tables shall be included which show the maximum allowable gauge reading for each gauge and loading condition. Other tables shall be included which show the requirements for all other test criteria.

Each test procedure shall contain a table of predicted strain (or stress) at selected strain gauge locations. This table shall list the strain gauge number, predicted strain (or stress) from the stress analysis, the location of the strain, a space to enter the actual strain (or stress) and a space to enter the calculated percent difference, defined as:

Percentage Differences = \([\frac{{\text{Actual} - \text{Predicted}}}{{\text{Actual}}} \times 100}\]

16.5.19.1.2 Configuration

The locomotive shall be a structurally complete shell including flooring, but excluding such items as exterior and interior trim, windows, doors, seats, lights, interior lining, insulation, or any other components that shall obscure any structural member from view or that shall interfere with the performance of the test. Equipment shall be simulated by equivalent weights at their respective locations. For the test, the locomotive body shall be supported on the trucks or equivalent supports to allow longitudinal movement.
16.5.19.1.3 Strain Gauges

A minimum of 240 strain gauges shall be applied to measure the strain of structural members during the compression tests. A minimum of 240 strain gauges shall be applied to measure the strain of structural members during the vertical load test. A minimum of 240 strain gauges shall be applied to measure the strain of structural members during the diagonal jacking test. In many cases the same strain gauge may be used for more than one test, and some gauges may be used for all tests. The location of strain gauges shall be based on the Contractor's experience, the stress analysis, and the Finite Element Analysis. The Contractor shall prepare drawings and sketches showing the location of every strain gauge. These drawings shall dimension the location of every gauge showing the distance from edges, connections and bends. The location on the upper or lower, inner or outer surface shall be noted on these drawings. These strain gauge locations shall be submitted for approval with the test procedure for this test at least 2 months before commencement of locomotive body structural testing.

The strain gauges shall be Micro Measurements SR-4 type, or an approved equal, or other approved gauges specifically suitable for the application. The gauges shall be calibrated in accordance with the manufacturer's instructions for the material being measured. The gauges shall be compensated for temperature.

For each post load test, there shall be a minimum of 100 strain gauges applied to the post and locomotive structure. Some of the gauges may be used for more than one test if their location on the structure is appropriate for both tests, but readings from at least 100 strain gauges in locations where the stress may be critical shall be obtained for each test.

16.5.19.1.4 Deflection Gauges

Vertical deflection of the body shall be measured at 11 places along each side sill; a total of 22 places per vehicle. All deflection gauges shall be electronic devices; dial indicators shall not be permitted. There shall be one gauge at each end of the vehicle, one at each bolster and one at the center. The remainder shall be equally spaced between the bolsters. Measurements shall be taken to the nearest 0.01 inch (0.25 mm) and the deflections shall be considered as the average of the readings taken on both sides. Deflection of the body with respect to the bolsters shall be determined by plotting the data determined above. The Contractor may submit alternate means of measuring body vertical deflection which provide equivalent accuracy for approval.

An approved deflection gauge shall be applied at each end of the vehicle at the end sill near the ram. These gauges shall be mounted to measure the horizontal deflection of the shell during compression testing.

Approved deflection gauges shall be applied to the four corners of the underframe and at the lowering jack during the diagonal jacking test. These gauges shall measure the vertical deflection of the locomotive shell during the test.

During the vertical load test, the changes in transverse width of the shell shall be measured and recorded in an approved manner.

The deflection gauges shall have an electric output compatible with the data logging apparatus used with the strain gauges. All deflections shall be recorded simultaneously with the strain gauge recordings.
In addition to the above electronic recordings, five dial indicators of sufficient stroke shall be employed to measure the vertical deflection at the center of both side sills, the longitudinal deflection at the anti-climber next to the ram and next to the reaction at the opposite end of the locomotive. The fifth indicator shall be located next to the lowering jack during the diagonal jacking test. These dial indicators shall be read and manually recorded at every load step.

To measure the bending of the collision posts during the post tests, deflection gauges shall be applied to the post at a minimum of four places on each post being tested: top, bottom, middle, and load application point. These gauges shall be mounted to measure the motion of the post in the direction of the applied force. In addition, a dial indicator shall be mounted at the middle of the post, to measure the motion perpendicular to both the axis of the post and the direction of loading, in each test.

16.5.19.1.5 Load Cells

In order to verify the accuracy of the applied vertical and compressive loads, load cells shall be provided at the appropriate location for each test. Each load cell shall be calibrated to 1% accuracy and certified within 2 months before commencement of these tests over the full range of 1.5 times the maximum load to which the load cell shall be subjected during these tests. The load cells shall have electric output compatible with the data logging apparatus used with the strain gauges. All loads shall be recorded simultaneously with the strain gauge recordings.

A single load cell shall be placed at the end of the ram for the compression test. A load cell shall be placed at each spring location for the vertical test. A load cell shall be placed at each jack location for the diagonal jack test. Load cell readings shall be taken and recorded at each step of the vertical and compression load application and removal process.

16.5.19.2 Compression Load Test

16.5.19.2.1 Body Test Description

The ability of the body shell structure to resist the compression load specified in Section 3.5 shall be tested. During the compression test, the body shall be supported on trucks or a simulation thereof to allow frictionless longitudinal movement. The body shall be loaded with sufficient dead weight to bring the total body weight up to that of an empty a fully loaded, ready-to-run vehicle, including full crew. This loading shall be distributed in proportion to the distribution of weight in the finished vehicle. The force of the testing machine shall be applied by hydraulic power and the force measured by a means independent of those producing the force. A compression test load of 800,000 lbs. shall be applied to the rear draft stop in the draft gear housing at the centerline of draft by means of a controlled hydraulic ram. If a "shear-back" coupler or drawbar is used, the specified 800,000 lb buff load shall be applied to the anti-climber. Cushioning means, such as lead sheets, shall be provided to assure uniform bearing. This test load shall be applied horizontally on the shell longitudinal centerline. No allowance shall be made for camber of the body. The load shall be applied in 200,000 lb. increments up to 600,000 lbs. and then in 100,000 lb. increments. The load shall be reduced to not more than 10,000 lbs. after each step. Strain gauge and deflection readings shall be taken at each load increment and at each relaxation of load. The ram shall be supported at the end sill but shall remain free to move longitudinally with respect
to the end sill. Additionally, the ram shall be supported in a manner such that no portion of the locomotive body weight is transferred to the rams due to the locomotive body humping tendency during compression testing. The full locomotive body weight shall be supported on the trucks or simulation thereof during the compression load application.

Prior to testing, all strain and deflection gauges shall be zeroed. The strain and deflection shall be measured and electronically recorded for each step of the compression test.

The load versus strain of critical members or members showing high stress shall be plotted for every load during the tests. The deflection points shall also be plotted during the tests.

Due to the critical nature of this test, the entire procedure shall be videotaped by the Contractor with at least three sound equipped color video cameras. The cameras shall be arranged in the appropriate locations to view and record key areas. All videos taken during this test shall become the property of SEPTA. The Contractor shall also prepare a still color photographic record of the test which shows all the details of the test setup and the test specimen loading.

16.5.19.2.2 Body Test Criteria

The shell shall be compliant with respect to compression loads if all of the following are met:

1. Plotted vertical deflections, measured on both sides of the shell midway between bolsters and taken as the average thereof, do not vary by more than plus or minus 5% from a straight line (linear) deflection curve, with one end point at the origin and the other at the point which represents the measured deflection for a load of 800,000 lbs.

2. The vertical deflection of each side of the test structure shall be within ±10 percent of the value determined by the analysis.

3. Maximum stresses calculated from strain readings in any structural element do not exceed the corresponding allowable stresses as specified in Section 3.6 and approved, prior to starting the test program.

4. Strain readings plotted against load do not vary by more than ±5 percent from a straight line (linear) curve, with one end point at the origin (no load) and the other near the point, which represents the measured strain, at maximum load.

5. Recorded residual vertical deflection between bolsters following removal of the maximum vertical test load does not exceed 0.03 inch.

6. The residual horizontal deflection between ends following removal of the maximum load does not exceed 0.03 inch.

7. Indicated residual strains at strain gauges on principal structural elements following removal of the maximum vertical loading do not exceed the maximum error resulting from the accuracy of the instrumentation.
8. There shall be no visual permanent deformation, fractures, cracks, or separations in the vehicle structure. Broken welds shall be jointly inspected by the Contractor and SEPTA to determine if the failure is the result of weld quality or stress.

9. Camber at the center of the structure shall not go negative.

10. The flatness and straightness of structural members meet the requirements of Section 3.4.

### 16.5.19.2.3 Cab Refuge Test Description

A cab refuge shall be constructed and a test shall be conducted to confirm proof of design. The test procedure shall be the subject of a Design Review in conjunction with the FEA submittals, required in Section 3.6.

The force of the testing machine shall be applied by hydraulic power and the force measured by a means independent of those producing the force.

Cushioning means, such as lead sheets, shall be provided to assure uniform bearing.

The loads shall be applied in 25% of load or 200,000 lbs steps, whichever is the least until 80% of load is applied and then the steps shall be in 50,000 lbs. steps. The load steps shall be reduced to not more than 25,000 lbs after the 800,000 lbs. level is reached up to 1,000,000 lbs. maximum limit or where permanent deformation is observed. Strain gauge and deflection readings shall be taken at each load increment and relaxation of each step.

Prior to testing, all strain and deflection gauges shall be zeroed. The strain and deflection shall be measured and electronically recorded for each step of the compression test.

The load versus strain of critical members or members showing high stress shall be plotted for every load during the tests. The deflection points shall also be plotted during the tests.

Due to the critical nature of this test, the entire procedure shall be videotaped by the Contractor with at least three sound equipped color video cameras. The cameras shall be arranged in approved locations to view and record key areas. All videos taken during this test shall be property of SEPTA.

### 16.5.19.2.4 Cab Refuge Test Criteria

The cab refuge shall be compliant with respect to compression loads if all of the following are met:

1. Maximum stresses calculated from strain readings in any structural element do not exceed the corresponding allowable stresses as specified in Section 3.5 and approved, prior to starting the test program.
There shall be no visual permanent deformation, fractures, cracks, or separations in the cab refuge structure. Broken welds shall be jointly inspected by the Contractor and SEPTA to determine if the failure is the result of weld quality or stress.

### 16.5.19.3 Vertical Load Test

#### 16.5.19.3.1 Test Description

Vertical load testing is concurrent with the crush test.

The locomotive body specimen supported on trucks or a simulation shall be subjected to a vertical load test. A test load equal to the static vertical operating load specified in Section 3.5.3 shall be applied to the specimen. The load shall be applied in four approximately equal increments resulting in a total of five vertical load readings. One of these increments shall be equivalent to a ready-to-run locomotive body weight including a full crew load. The test load may be applied by means of weights or jacks, but shall be distributed in proportion to the distribution of weight in the finished locomotive. The specimen shall be unloaded in the increments that it was loaded, in reverse order. Strain gauge and deflection readings shall be taken at each load increment.

During the vertical load test, a measurement of locomotive body vertical deflection shall be made along both locomotive body side sills at each test load applied.

#### 16.5.19.3.2 Test Criteria

A weight equivalent to major equipment items shall be loaded into the structure at the appropriate mounting pads.

The shell shall be compliant with respect to the vertical load test if all of the following are met:

1. Plotted vertical deflections, measured on both sides of the shell midway between bolsters and taken as the average thereof, do not vary by more than plus or minus 5% from a straight line (linear) deflection curve, with one end point at the origin and the other at the point which represents the full load.

The vertical deflection of each side of the test structure shall be within ±10 percent of the value determined by the analysis.

Maximum stresses calculated from strain readings in any structural element do not exceed the corresponding allowable stresses as specified in Section 3.6 and approved, prior to starting the test program.

Strain readings plotted against load do not vary by more than ±5 percent from a straight line (linear) curve, with one end point at the origin (no load) and the other near the point, which represents the measured strain, at maximum load.
Recorded residual vertical deflection between bolsters following removal of the maximum vertical test load does not exceed 0.03 inch.

The residual horizontal deflection between ends following removal of the maximum load does not exceed 0.03 inch.

Indicated residual strains at strain gauges on principal structural elements following removal of the maximum vertical loading do not exceed the maximum error resulting from the accuracy of the instrumentation.

There shall be no visual permanent deformation, fractures, cracks, or separations in the vehicle structure. Broken welds shall be jointly inspected by the Contractor and SEPTA to determine if the failure is the result of weld quality or stress.

Camber at the center of the structure shall not go negative.

The flatness and straightness of structural members meet the requirements of Section 3.4

### 16.5.19.4 Diagonal Jacking Test

#### 16.5.19.4.1 Test Description

The same body shell tested as described in Section 16.5.19.3 shall also be subjected to a diagonal jacking test. The test shell loaded to equal its empty weight with trucks (or equivalent weight) hanging from the bolsters shall be supported on the four most outboard jack pads. All supports shall be equipped with load cells. One support shall be lowered in five equal steps to a load of less than 10% of its original load. The jack shall then be returned to its original position - i.e., zero on the deflection gauge next to the jack.

Prior to testing, all strain and deflection gauges shall be zeroed. The load, strain, and deflections shall be measured and recorded electronically for each step of jacking test.

#### 16.5.19.4.2 Test Criteria

The locomotive shell shall be Specification compliant with respect to the diagonal jack test if all of the following are met:

1. Maximum stresses calculated from strain readings in any structural element do not exceed the corresponding allowable stresses specified in Section 3.5 and approved, prior to the start of the test program.

Indicated residual strains at strain gauges active for this test following removal of the vertical and horizontal test loads do not exceed the maximum error resulting from the accuracy of the instrumentation.
There are to be no visual permanent deformations, fractures, cracks or separations in the vehicle structure. Broken welds shall be jointly inspected by the Contractor and SEPTA to determine if the failure is the result of weld quality or stress.

The locomotive body shall be compliant with respect to the diagonal jack test if all of the following are met:

1. Plotted vertical deflections, measured at the location of the lowered jack, do not vary by more than plus or minus 5% from a straight line (linear) deflection curve, with one end point at the origin and the other at the point which represents the full deflection.

Maximum stresses calculated from strain readings in any structural element do not exceed the corresponding allowable stresses as specified in Section 3.5 and approved, prior to starting the test program.

Strain readings plotted against load do not vary by more than ±5 percent from a straight line (linear) curve, with one end point at the origin (no load) and the other near the point, which represents the measured strain, at maximum load.

Recorded residual vertical deflection between bolsters following removal of the maximum vertical test load does not exceed 0.03 inch.

The residual horizontal deflection between ends following removal of the maximum load does not exceed 0.03 inch.

Indicated residual strains at strain gauges on principal structural elements following removal of the maximum vertical loading do not exceed the maximum error resulting from the accuracy of the instrumentation.

There shall be no visual permanent deformation, fractures, cracks, or separations in the vehicle structure. Broken welds shall be jointly inspected by the Contractor and SEPTA to determine if the failure is the result of weld quality or stress.

Camber at the center of the structure shall not go negative.

The flatness and straightness of structural members meet the requirements of Section 3.4.

16.5.19.5 Collision and Corner Posts

The ability of the locomotive to resist the collision post loads described in Section 3.5.5 shall be tested as required by APTA SS-C&S-034-99 Rev 2, Section 8.3 and 5.3.1.2.1, AAR MSRP S-580, Section 6.2, 7.2 or 8.3 as appropriate, and 49 CFR 238.211. These tests shall be conducted in two parts. The first part shall be all tests which have a pass-fail criterion equal to or less than permanent deformation (elastic tests). These tests shall be performed on the same test specimen as used for the locomotive body compression and vertical load tests. The second part shall be a test of the primary center collision post loaded at 18 inches above the floor, sufficient to cause permanent deformation (elastic-plastic test). The second part
shall require the construction of a model of the front end of the locomotive up to the bolster. The model shall be a duplication of all structure which supports or influences the support of the post(s).

### 16.5.19.5.1 Collision Posts

1. **Elastic Test Description**
   During the elastic collision post load tests, the locomotive body shall be supported on trucks or a simulation thereof to allow free longitudinal movement. The locomotive shell shall be loaded with sufficient dead weight to bring the total body weight (of test specimen) up to that of a fully loaded locomotive car body, including full crew. This loading shall be distributed in proportion to the distribution of weight in the finished locomotive.

   The specimen shall be instrumented as required for the locomotive and collision post in Section 16.5.19.1.3, Section 16.5.19.1.4 and Section 16.5.19.1.5. The strain gauges and deflection gauges shall be installed in the same locations so that the structural equivalence of the model to the locomotive body can be resolved.

   The test load shall be applied by means of a controlled hydraulic ram, and the force measured by a means independent of that producing the force. A fixture and cushioning means, such as load sheets, shall be provided to assure uniform bearing and prevent crippling around the area of force application. This fixture and cushion shall not be attached to the post. The test load shall be applied horizontally parallel to the locomotive longitudinal centerline. The load shall be applied in increments of 25, 50, 75, 87.5 and 100 percent of full load. The load shall be reduced to not more than 2 percent of full load after each step. Strain gauge and deflection readings shall be taken at each location increment and at each relaxation of load. The ram shall be supported at the locomotive end but shall remain free to move longitudinally with respect to the locomotive end.

   The production collision posts and associated structures shall be tested as part of the cab refuge test and is required to demonstrate the strength of the structure from above the 30” level to the roof junction in compliance with Section 3.5.

   The placement of the load shall be for the worst case condition.

   Placement of load cells, strain gauges, and deflection gauges shall be submitted and approved after the approval of the collision post and attachment analysis and prior to testing.

   Prior to testing, all strain and deflection gauges shall be zeroed. The load, strain and deflections shall be measured and recorded electronically for each step of the test.

   A longitudinal test load as specified in APTA SS-C&S-034-99 Rev 2, Section 8.3 and 5.3.1.2.1 shall be applied to the collision post at 30 inches above top of underframe. This elastic test can be conducted as part of the elastic-plastic tests, however, the elastic test load shall not be less than 60,000 lbf as required by APTA SS-C&S-034-99 Rev 2, Section 8.3 and 5.3.1.2.1(c). There shall be no permanent deformation of the post or supporting structure at the 60,000 lbf load.
Test Criteria

Maximum stresses calculated from strain readings in any structural element shall not exceed the corresponding allowable stresses specified in Section 3.5 and approved, prior to the start of the test program.

The locomotive body shall be compliant with respect to the collision post elastic test if all of the following are met:

a) Deflection readings plotted against load do not vary by more than ±5 percent from a straight line (linear) deflection curve, with one end point at the origin (no load) and the other near the point which represents the measured deflection at maximum load.

b) Maximum stresses calculated from strain readings in any structural element do not exceed the corresponding allowable stresses as specified in Section 3.6 and approved, prior to starting the test program.

c) Strain readings plotted against load do not vary by more than ±5 percent from a straight line (linear) curve, with one end point at the origin (no load) and the other near the point, which represents the measured strain, at maximum load.

d) Indicated residual strains at strain gauges on principal structural elements following removal of the maximum vertical loading do not exceed the maximum error resulting from the accuracy of the instrumentation.

e) There shall be no visual permanent deformation, fractures, cracks, or separations in the vehicle structure. Broken welds shall be jointly inspected by the Contractor and SEPTA to determine if the failure is the result of weld quality or stress.

f) The flatness and straightness of structural members meet the requirements of Section 3.3.

Elastic-Plastic Test Description

The ability of the connections between the collision posts and the locomotive body structure to withstand a longitudinal load equal to the ultimate load carrying capacity of the post as specified in Section 3.5.2.5 shall be tested.

The test specimen shall be a full scale structural model of a cab end of the locomotive. The structural model shall contain all structural elements required to support the collision posts including the end underframe and roof extending from the forward end of the end frame to the bolster. All connections shall be the same as on production locomotives. The bolster end of the model shall be attached to a rigid fixture so that the stresses in the post and its supporting structure shall be the same as it would be in a locomotive subjected to the same load.

The longitudinal test load shall be applied to the collision post as described in APTA SS-C&S-034-99 Rev 2, Section 8.3 and 5.3.1.2.1.

The compression test load shall be applied by means of a controlled hydraulic ram, and the force measured by a means independent of that producing the force. A fixture and cushioning
means, such as lead sheets, shall be provided to assure uniform bearing and prevent crippling around the area of force application. This fixture and cushion shall not be attached to the post. The test load shall be applied horizontally parallel to the locomotive longitudinal centerline. The initial load shall be applied in increments of the same magnitude as those used during the collision post elastic load test. The load shall be reduced to not more than 2 percent of full load after each step. Strain gauge and deflection readings shall be taken at each load increment and at each relaxation of load.

The strain gauge readings and deflections measured during this test shall be within ±5 percent of the gauge readings for the same load and location measured during the collision post elastic test. If difference between the two tests are obtained, the fixture and/or the model shall be corrected until 5 percent agreement between the two tests are obtained.

After agreement between the two tests is demonstrated, the collision post shall continue to be loaded in increments of 25 percent of the full load specified in the primary center collision post longitudinal load test until the load carrying capacity of the collision post is obtained. At each 25 percent load increment, all load cell(s), strain gauges, and deflection gauges shall be recorded. The load need not be relaxed at each step.

As specified by APTA SS-C&S-034-99 Rev 2, Section 8.3.4, the collision post elastic-plastic requirements shall be satisfied if the connections between the post and the supporting structural members are not completely separated and the ultimate strength of the structure is not exceeded.

Test Criteria
The collision post shall be compliant with this Specification if all of the following are met:

a) All strain gauges and deflection gauges have the same readings (within ±5 percent) for the same loads at the same locations as the collision post elastic load test for 0 to 100 percent of the loads specified in Section 3.5.2.5.

b) Under the ultimate load carrying capacity of the post, as defined above, the connections between the collision post and all other structural members are not broken.

16.5.19.5.2 Corner Posts

1. Elastic Test Description
During the elastic corner post load tests, the locomotive body shall be supported on trucks or a simulation thereof to allow free longitudinal movement. The locomotive shell shall be loaded with sufficient dead weight to bring the total body weight (of test specimen) up to that of a fully loaded locomotive car body, including full crew. This loading shall be distributed in proportion to the distribution of weight in the finished locomotive.

The specimen shall be instrumented as required for the locomotive and collision post in Section 16.5.19.1.3, Section 16.5.19.1.4 and Section 16.5.19.1.5. The strain gauges and deflection gauges shall be installed in the same locations so that the structural equivalence of the model to the locomotive body can be resolved.
The test load shall be applied by means of a controlled hydraulic ram, and the force measured by a means independent of that producing the force. A fixture and cushioning means, such as load sheets, shall be provided to assure uniform bearing and prevent crippling around the area of force application. This fixture and cushion shall not be attached to the post. The test load shall be applied horizontally in the worst case of longitudinally or transversely as specified in APTA SS-C&S-034-99 Rev 2, Section 8.3 and 5.3.1.2.1. The load shall be applied in increments of 25, 50, 75, 87.5 and 100 percent of full load. The load shall be reduced to not more than 2 percent of full load after each step. Strain gauge and deflection readings shall be taken at each location increment and at each relaxation of load. The ram shall be supported at the locomotive end but shall remain free to move longitudinally or transversely with respect to the locomotive end.

Placement of load cells, strain gauges, and deflection gauges shall be submitted and approved after the approval of the collision post and attachment analysis and prior to testing. Prior to testing, all strain and deflection gauges shall be zeroed. The load, strain and deflections shall be measured and recorded electronically for each step of the test.

Test Criteria

The locomotive body shall be compliant with respect to the corner post elastic test if all of the following are met:

a) Deflection readings plotted against load do not vary by more than ±5 percent from a straight line (linear) deflection curve, with one end point at the origin (no load) and the other near the point which represents the measured deflection at maximum load.

b) Maximum stresses calculated from strain readings in any structural element do not exceed the corresponding allowable stresses as specified in Section 3.6 and approved, prior to starting the test program.

c) Strain readings plotted against load do not vary by more than ±5 percent from a straight line (linear) curve, with one end point at the origin (no load) and the other near the point, which represents the measured strain, at maximum load.

d) Indicated residual strains at strain gauges on principal structural elements following removal of the maximum vertical loading do not exceed the maximum error resulting from the accuracy of the instrumentation.

e) There shall be no visual permanent deformation, fractures, cracks, or separations in the vehicle structure. Broken welds shall be jointly inspected by the Contractor and SEPTA to determine if the failure is the result of weld quality or stress.

f) The flatness and straightness of structural members meet the requirements of Section 3.3.

Elastic-Plastic Test Description
The ability of the connections between the corner posts and the locomotive body structure to withstand the worse of a longitudinal or transverse load equal to the ultimate load carrying capacity of the post as specified in Section 3.5.3 shall be tested.

The test specimen shall be a full scale structural model of a cab end of the locomotive. The structural model shall contain all structural elements required to support the corner posts including the end underframe and roof extending from the forward end of the end frame to the bolster. All connections shall be the same as on production locomotives. The bolster end of the model shall be attached to a rigid fixture so that the stresses in the post and its supporting structure shall be the same as it would be in a locomotive subjected to the same load.

The worse of the longitudinal or transverse test load shall be applied to the corner post as described in APTA SS-C&S-034-99 Rev 2, Section 8.3 and 5.3.1.2.1.

The compression test load shall be applied by means of a controlled hydraulic ram, and the force measured by a means independent of that producing the force. A fixture and cushioning means, such as lead sheets, shall be provided to assure uniform bearing and prevent crippling around the area of force application. This fixture and cushion shall not be attached to the post. The test load shall be applied horizontally in the worst case of longitudinally or transversely as specified in APTA SS-C&S-034-99 Rev 2, Section 8.3 and 5.3.1.2.1. The initial load shall be applied in increments of the same magnitude as those used during the corner post elastic load test. The load shall be reduced to not more than 2 percent of full load after each step. Strain gauge and deflection readings shall be taken at each load increment and at each relaxation of load.

The strain gauge readings and deflections measured during this test shall be within ±5 percent of the gauge readings for the same load and location measured during the corner post elastic test. If difference between the two tests are obtained, the fixture and/or the model shall be corrected until 5 percent agreement between the two tests are obtained.

After agreement between the two tests is demonstrated, the corner post shall continue to be loaded in increments of 25 percent of the full load specified in the corner post load test until the load carrying capacity of the cornerpost is obtained. At each 25 percent load increment, all load cell(s), strain gauges, and deflection gauges shall be recorded. The load need not be relaxed at each step.

As specified by APTA SS-C&S-034-99 Rev 2, Section 8.3.4, and the collision post elastic-plastic requirements shall be satisfied if the connections between the post and the supporting structural members are not completely separated and the ultimate strength of the structure is not exceeded.

The corner post shall be compliant with this Specification if all of the following are met:

1. All strain gauges and deflection gauges have the same readings (within ±5 percent) for the same loads at the same locations as the collision post elastic load test for 0 to 100 percent of the loads specified in Section 3.5.3.
2. Under the ultimate load carrying capacity of the post, as defined above, the connections between the corner post and all other structural members are not broken.

16.5.19.6 Structural Changes

Any structural changes or modifications made during any test or during construction and assembly shall be subjected to the entire test series. All vehicles constructed prior to and subsequent to these tests shall incorporate these structural changes or modifications.

16.5.20 Seats

One seat frame, cushion, back, and seat set of upholstery material of each type shall be tested to confirm compliance with the requirements of Section 4.6.1.

One sample seat shall be tested by the manufacturer for all criteria specified in APTA Standard SS-C&S-016-99 and submitted to the Engineer with a detailed test report. Seat cushions and upholstery shall be tested to verify compliance with Section 15 requirements.

16.5.21 Communications System

The communication system supplier shall conduct a test at its facility on the first locomotive communications equipment to demonstrate compliance with FCC, IEEE, and Section 14.0 requirements.

Each component of the communications system, including the GPS, automatic vehicle location system and wireless local area network, shall be tested to verify that it functions in accordance with the requirements of Section 13. Wayside simulations shall be performed as approved by the Engineer to fully verify all functions. All equipment which is installed under the Contract on the SEPTA wayside or the SEPTA Control Center shall also be tested to verify compliance. The ability to modify software data files and change parameters for the communications system equipment shall be successfully demonstrated.

16.5.22 Floor Panel Fire Resistance

A sample of materials representing structural flooring, floor panels and floor covering along with a representative section of cab structure, shall be tested to verify the ability to withstand the requirements of ASTM E119-07, when exposed for 15 minutes at up to 1400°F on the material underside. The Contractor shall provide test procedure, test report and a DVD with video of actual testing.

16.5.23 Elastomer Tests

The Contractor shall perform at its expense the following tests. The test specimens shall be cut from the extruded material, and at least one tensile strength and elongation test and one accelerated aging test shall be made on the material used for each locomotive order. If the compound or cure, or both, are changed during the production of material for one locomotive order, at least one test of each type shall be made for each different batch. When testing the 6 inch by 0.5 inch ASTM dumbbell type test specimen (or smaller size if the size of the part necessitates) by the methods specified in ASTM
Specifications D 318, D 318b, D 3188, D 3190, D 3192 and D 412 for neoprene door edges, the tensile strength shall not be less than 1,700 pounds/square inch and elongation shall not be less than 350 percent. The tensile strength of the neoprene shall not be reduced more than 25 percent when subjected to accelerated aging by the methods specified in ASTM Specification D 573.

16.5.24 Main Transformer

16.5.24.1 General

The main transformer manufacturer and the Contractor shall perform tests on the first completely assembled transformer to establish the transformer characteristics and to verify compliance with the requirements of this Specification. If the first transformer does not meet the specified requirements, corrective action shall be taken and implemented and a minimum of two additional transformers shall be tested successfully.

All tests shall be performed in accordance with ANSI Specifications numbers C57.12.00 and C57.12.90. Each transformer shall be given the standard Railroad tests. A basic impulse insulation level (BIL) test shall be made on the first production transformer of all primary windings. The 25,000 volts primary winding configuration shall withstand a 200,000 volts basic impulse level test, and the 11,000 volts primary winding configuration shall withstand an 110,000 volts basic impulse level test. In the event this transformer fails to pass the impulse test, the next three production transformers shall also be given this impulse test. Should failure occur on any of these three transformers, then every transformer produced shall be given and must pass an impulse test. The first production transformer shall be given both a heat run test to verify cooling system capability, and a cold start test to verify coolant pump capability with viscous coolant. The heat run test shall be conducted in a heat chamber held at a constant temperature of 140 degrees F during the test. The transformer shall first be heat soaked for a period of 6 hours, and then energized at full rated power for a 2 hour period without showing evidence of any overheating or damage. The cold start test shall be conducted in a cold chamber held at a constant temperature of minus 7 degrees F during the test. The transformer shall first be cold soaked for a period of 10 hours, and then energized with full auxiliary winter loads (full heating loads) for a 1 hour period. The coolant pump shall start and operate normally without any damage, and the transformer shall operate without showing evidence of any overheating or damage.

16.5.24.2 Initial Tests

These tests shall be conducted by the manufacturer in accordance with ANSI C57.12.00, C57.12.90, and C57.98 standards. These tests shall include:

- Full load Temperature Rise (Heat Run);
- Impulse Test;
- Short Circuit Capability;
- Audible Sound Level;
- Attachment Devices;
- Pressure Test;
- Inrush Current Test;
- Impedance Voltage Test

16.5.24.3 System Test
The first completed transformer shall be connected to a load simulating the worst case vehicle operating conditions and covering the environmental ranges and supply voltages given in Sections 2.2.1, 2.2.8. These tests shall be performed over the entire input voltage range.

Instrumentation sufficient to determine the transformer performance characteristics when operating in the system environment and to verify compliance with the Specification requirements shall be provided. The instrumentation shall include provisions to record voltage and current for each of the transformer windings on an approved recorder. The instrumentation shall have the capability to record both instantaneous and true RMS values of current and voltage. Test plan for this component shall be supplied to SEPTA for approval.

16.5.24.4 Fan and Pump Motor Tests
The following tests shall be performed by the manufacturer on the transformer fan and pump motors in accordance with IEEE Standard No. 11.

- Fan and pump motor power and current measurements during 2 hours of operation at nominal, minimum, and maximum input voltage levels.

- Cold and hot winding resistance checks.

- Noise and vibration level measurements for both fan and pump motor.

16.5.25 Relays and Contactors
Test data for one type of each relay and contactor shall be provided by the manufacturer to verify compliance with the design requirements for that specific device and the Specification requirements defined in Section 15.25.2.

16.5.26 Electrical and Electronic Panels
One type of each electric and electronic panel shall be tested by the manufacturer to verify compliance with the design requirements for that specific panel and the Specification requirements defined in Section 15.0.
16.6 ENGINEERING PRE-DELIVERY TESTING

Pre-delivery testing refers to the test of the Pilot Locomotive at the Contractor's final assembly facility prior to shipment. To implement pre-delivery testing of the locomotives, the Contractor shall provide at its assembly facility a test track on which safe operation up to 30 miles/hour can be conducted. In addition, this track shall be equipped with power supply and catenary parameters simulating SEPTA’s Railroad Division conditions on which it shall be possible to test performance as shown below.

Engineering Pre-Delivery Testing

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16.6.1 Clearances

Truck clearance, coupler/drawbar clearance, locomotive body clearance, snow plow clearance, and cab signal receiver clearance tests shall be conducted on the first locomotive and three (3) other locomotives, selected by SEPTA, to verify that the entire locomotive, including all equipment, complies with the restrictions imposed by the Clearance Diagram specified in Section 2.2.2. A static roll test and running test on super-elevated track to measure and record static and dynamic roll shall be conducted as part of this test.

Prior to manufacturing, the Contractor shall submit documentation which verifies conformance of the entire locomotive to all dimensional restrictions imposed by the specified Clearance Diagram.

16.6.1.1 Vehicle Clearance

To verify the clearance provided by the truck design, the first vehicle of each type with simulated full load shall be run up on a rail or blocking on one side to simulate 5-1/2 inches of super-elevation. Lateral displacement and roll angle of the locomotive body shall be measured. Refer to Clearance Diagram A-05-1355, Rev. E for maximum roll angle permitted. In the event that the degree of motion restriction required is not attained as indicated by the test, the truck design shall be corrected, the truck retested,
and all trucks, including those installed under the vehicles, shall be modified or reconfigured in accordance with the corrected design.

In addition, tests shall be performed on a superelevation of both 4 inches and 6 inches to measure body roll and wheel unloading to verify compliance with 49 CFR Part 213.57 (d). The Contractor shall provide a test report providing all data required by 49 CFR Part 213.57 (d), and shall fully support SEPTA's submission to the FRA with additional information as requested by the FRA.

16.6.1.2 Equalization

To verify the equalization provided by the truck design, the first locomotive shall be operated at track speed through a curve as specified in Section 10.3.4. At no point shall any wheel tread lose contact with the running surface of the rail. In the event that suitable equalization is not attained as indicated by the results of the tests, the truck design shall be corrected, the truck retested, and all trucks, including those installed under the vehicles, shall be modified or reconfigured in accordance with the corrected design. The test track shall be provided by SEPTA.

16.6.2 Weight Distribution

Weight distribution test shall be performed on the first locomotive to verify compliance with the requirements of Section 2.2.3.2.

16.6.3 Locomotive HVAC Test

The locomotive shall be functionally tested for basic HVAC operation prior to or during the commissioning period.

16.6.3.1 General

The first locomotive, complete in all respects, shall be tested for correct temperature distribution and functioning of the HVAC System.

Testing shall include a functional check of all apparatus including temperature sensors and controls, and temperature and relative humidity verifications to show compliance with the specified cooling requirements with all apparatus operating at nominal HEP voltage.

16.6.3.2 Freeze Protection Test

Freeze protection testing shall be conducted as part of the heating system tests under the specified ambient conditions. Testing shall verify system operation and unrestricted operation at -22°F ambient, as specified in Section 6.3.

16.6.4 Lighting

Light intensity readings of all lighting systems shall be taken (without light from other sources) to verify conformance with the requirements in Sections 5.6 and 8.4.
16.6.5 Brake Pad/Shoe Force Tests

Tests shall be conducted on the first locomotive to verify the actual force produced at the brake pad by the disc brake assembly, and at the brake shoe by the tread brake unit at both a handbrake and a non-handbrake location agree with calculated values. Tests shall be conducted with brake cylinder pneumatic pressures in 5 pounds/square inch increments, from 0 pounds per square inch to the maximum used, and from application of the handbrake.

16.6.6 Parking Brake Test

16.6.6.1 General

A test of the adequacy of the parking brake design shall be conducted on the first locomotive to verify that the requirements of Section 11.6 are met. Specification compliance shall be demonstrated by the tests below.

16.6.6.2 Brake Shoe Force Measurement

Brake shoe force shall be measured on the parking brake-actuated brake units on one vehicle of each type. The force shall be measured with a load cell, approved by the brake unit manufacturer.

16.6.6.3 Indicator Sensor

A test shall be conducted to verify that the function and performance of the parking brake indicator sensor complies with the requirements defined in Section 12.6.

16.6.6.4 Holding Test

A test shall be conducted to demonstrate that the parking brake can hold a fully loaded locomotive and a similarly loaded individual unit, selected by SEPTA, on the maximum grade specified in Section 12.6. The test may be conducted on level tangent track with an approved method to simulate the equivalent force of a maximum grade. The test shall be conducted with both new and fully worn-in shoes.

16.6.7 HEP Inverters

The Contractor shall conduct tests on all inverters in one of the first two locomotives to demonstrate that the inverters comply with the requirements of Section 8.0. These tests shall include functional testing to verify correct response to fault and failure conditions, fault annunciation, load shedding, and auto switch-over. During these tests the Contractor shall record, as a minimum, the following at each inverter on approved high speed, fast response recorders:

- Inverter input and output voltage;
- Inverter input and output current;
- Inverter frequency;
- Load shedding signal;
- Step load responses, 25% steps and from no load to full load.

The Contractor shall operate the inverter instrumentation throughout the inverter tests and during all of the other locomotive performance testing to verify consistent, reliable inverter performance. The chart recordings shall become the property of SEPTA. Chart recordings which contain representative samples of inverter operation taken during the inverter functional tests and the Locomotive Performance tests shall be included in the inverter test report.

### 16.6.8 Propulsion and Braking Tests

Propulsion and braking tests shall be performed on the Contractor's test track on the first locomotive. These tests shall be sufficient to qualify the locomotive for successful performance of the testing specified in Section 16.6.8 by employing those procedures in an approved form appropriate for the site. This shall include verification of the high voltage control system controls and response to faults. Catenary may be energized at 12,500 volts at 60 Hertz for these tests. The Contractor shall prepare a procedure for this to be approved by the Engineer.

### 16.6.9 Monitoring and Diagnostic Systems

The locomotive monitoring and diagnostic systems supplier shall conduct a test at its facility on the first locomotive equipment to demonstrate compliance with FRA, and Section 14.0 and 15.0 requirements.

The diagnostic function of each individual system shall be tested as a separate test or in combination with other functional testing. The PTU shall be used to successfully access all available locomotive subsystems. The capability to modify all password-protected software parameters shall be verified. The interface and functionality of the Locomotive Data Management System (LDMS) and the wireless Local Area Network shall be tested. Testing shall be conducted to insure that locomotive faults can be downloaded over the network and that the GPS system database can be updated, the LDMS and wireless LAN systems shall be fully functionally tested.

### 16.6.10 Trainline Tests

The first locomotive and the second locomotive shall be coupled together on the Contractor's test track, and all trainline functions, including coupling and uncoupling and diagnostic messages, shall be tested to verify correct operation.

### 16.6.11 Communications Tests

The first locomotive shall have all aspects of the communications system tested. All radio functions shall also be tested.
16.6.12 System Isolation

On the first locomotive, and another locomotive selected at random by SEPTA, each electrical subsystem shall be completely isolated from ground and/or B- by disconnecting the single return wire, for each system, designated for this purpose. With each subsystem so isolated and the B+ circuit breaker open, the subsystem resistance to B- shall be not less than 100 megohms. If any significant design change is made to any electrical subsystem or its wiring during the Contract, SEPTA may require that the capability of the subsystem isolation be re-demonstrated by the Contractor.

16.7 ENGINEERING ON-SITE PILOT LOCOMOTIVE and PILOT TRAIN TESTING

After the first locomotive has completed pre-delivery testing at the Contractor’s facility, it will be delivered to the SEPTA site in accordance with the requirements of Section 16, where they will undergo on-site performance testing. On-site testing shall be in accordance with all tests in this Section and Section 16.9. The locomotive and a 3-car consist will be tested together for these tests, unless otherwise specified or approval is granted by the Engineer, and hereafter shall be referred to as the Pilot Train.

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16.7.1 Locomotive Performance

16.7.1.1 General

The Contractor shall conduct the necessary tests to demonstrate compliance with all performance requirements specified in Section 2.2 and with the Vehicle Qualification test as defined in 49 CFR
213.345. This series of tests shall be used to determine the equipment settings and calibrations to be used for the locomotive commissioning program of Section 16.6 and 16.7.

As a minimum, two runs with the first production locomotive shall be made in each direction for each test condition in the propulsion kinematic test, braking kinematic test, and wheel slip control test. Test run requirements for the other locomotive performance tests are defined in the test description for those tests.

In addition to the requirements of Section 20.3, if the first production locomotive, or any equipment, fails to satisfy any of the specified performance and design criteria, the locomotive, with the necessary adjustments, shall be retested. Retesting shall continue until the specified performance and design criteria are met. If modifications are necessary, they shall be verified by appropriate retest, as determined and approved by SEPTA, prior to being applied on a fleet-wide basis.

All recorded data shall be corrected for voltage and grade as part of the Contractor's test report. A plot of brake cylinder pressure vs. the "apparent" (real tractive plus the effects of train resistance) tractive effort produced shall be made. All pertinent data from each test at each loading shall be represented on a single graph.

Test reports shall be forwarded to and become the property of SEPTA. Refer to Section 16.4 for additional test report requirements.

16.7.1.2 Instrumentation

The Contractor shall provide or lease a complete instrumentation package including data acquisition system, sensors, cables, wiring, and power supplies, as applicable. The details of the instrumentation shall be submitted for approval not later than 6 months prior to the commencement of testing under this Section. The proposal shall include model numbers and specifications which clearly state the function, accuracy and response characteristics of each item in the instrumentation package. Calibration methods and standards employed shall also be submitted. All calibrations shall be verified with instrumentation having up-to-date certifications of accuracy traceable to the National Institute of Standards and Technology (NIST). The entire instrumentation package shall be calibrated prior to testing, and recalibrated following installation on the first production locomotive and following any repair, rework, or re-setup. All calibration traces shall become part of the permanent test record.

These tests shall be performed using automated data acquisition and analysis software such as National Instruments Lab View or equivalent. Built-in software at the Locomotive Data Management System may also be used if all the required parameters are recorded. The test software shall display the parameters in real time and give the resulting acceleration/deceleration immediately after each run. The data record shall be convertible to a chart recorder type display format that can be displayed, printed and saved to removable media by the test train personnel. The Contractor shall supply a permanent test record on CD-ROM for each locomotive which shall include the test data and the software required to view and print the data in the chart recorder format.

This instrumentation shall operate using the locomotive's 120 AC auxiliary power supply system and a battery backup uninterruptible power supply. Internal combustion engines to drive a generator will not be allowed. Low voltage equipment must function over a voltage range of 25 to 45 volts DC and...
otherwise not be damaged by the voltage conditions below 25 volts. Isolation amplifiers and voltage dividers shall be provided as part of the instrumentation package to isolate the inside locomotive instrumentation wiring and equipment from high voltages; no exposed terminals with potential differences greater than 50 volts shall be permitted. The accuracy and response of the instrumentation shall be sufficient to determine the degree of compliance with the Technical Specification and design data. Any reference clocks shall not depend upon the frequency accuracy of the power supply for their timing accuracy. The Engineer shall approve all test instrumentation prior to any testing. These tests may also be witnessed by the FRA.

The high speed data acquisition system shall have a sufficient number of recording channels to demonstrate compliance with the requirements of Section 2.2. A minimum of three spare channels shall be provided for additional tests which may be requested by SEPTA.

All of the following tests shall be performed on the same marked location on the SEPTA Railroad Division/Northeast Corridor. The Contractor shall assume that the test track area will only be available from midnight to 5:00 AM. The Contractor shall select, with the Engineer's approval, a suitable test area and determine where each test shall start. The locations will be such that the opposite direction test run for a particular condition shall be at the same approximate location. The start location for each test shall be marked with permanent sign using either a letter or distance number that is acceptable to the Engineer. The Contractor shall supply the signs at least 30 days before the scheduled start of testing in order to allow SEPTA sufficient time to erect the signs before the start of testing. Prior to the start of the test program, a "shakedown" series of tests shall be run to determine the equipment settings and calibrations to be used for the test program.

16.7.1.3 Data Required

The following data is required to be simultaneously recorded for the first production locomotive performance test, as a minimum:

- Acceleration, both positive and negative.
- Traction motor current and torque on each motor. Separate recordings of motor output parameters shall be provided with voltage, current; frequency and phase relationship.
- Wheel slip control system operation on each axle.
- Brake pipe pressure.
- Brake cylinder pressure.
- Wheel surface and brake disc temperature on one axle.
- Catenary voltage and current.
- Train speed.
- Propulsion and braking signals.
• Distance intervals in 10 feet increments.
• A time clock reference with one second time intervals.
• DC link voltage
• Air spring pressure
• Event marker
• Sander operation

Additional data shall be recorded as required to demonstrate compliance with the requirements of Section 2.2.

16.7.1.4 Propulsion and Braking Performance Tests

The Pilot Locomotive/Pilot Train shall be run empty and again at each specified load for the performance standards. As a minimum, two runs in each direction shall be made for each test condition as listed in the following schedule. The Contractor shall supply all ballast and labor for loading and unloading locomotives to simulated loaded locomotive conditions.

As a minimum, the following tests shall be performed:

a) Propulsion:
   • Acceleration rates and maximum speed for each trainline power command, accelerating from a stop.
   • Time to travel one mile from a standing start with a maximum power command.

b) Braking:
   • Full service stops from 135, 100, 80, 50, and 35 miles/hour.
   • Full friction-only stops from 135, 100, 80, 50, and 35 miles/hour.
   • Emergency stops from 135, 100, 80, 50, and 35 miles/hour.

c) Wheel spin/slide tests in all power and braking modes to verify compliance with Sections 10 and 11, including reapplication of acceleration or braking at the jerk limited rate.

d) Testing of locomotive power consumption, to verify kWh/locomotive-mile consumption, to be performed from Suburban Station to Chestnut Hill East, Suburban Station to Chestnut Hill West, and Suburban Station to Paoli.

e) Testing of line voltage, current and waveform under regenerative conditions.
f) Additional tests, as needed, to verify compliance with the parameters that can not be evaluated by the tests listed above.

Using the data from the above tests, characteristic locomotive performance parameters and curves shall be generated for the evaluation of the test results of the production locomotives. The above shall include all air pressures, voltages and currents.

A plot of brake cylinder pressure versus the braking effort produced (derived from deceleration recordings and known loadings, minus known drift rates of the corresponding speed) shall be made. All pertinent data from each test at each loading shall be represented on a single graph.

All recorded data shall be corrected for voltage and grade factors as part of the Contractor's test report. Test reports shall be folded and placed in envelopes for storage, and provided to the Engineer. Records of current settings for acceleration and deceleration shall be furnished for each locomotive. An analysis and report on the suitability of the use of sanders shall also be performed.

If the Pilot Locomotive or any of its equipment fails to satisfy the specified performance and design criteria, the locomotive shall have the necessary adjustments made and be retested at the Contractor's expense.

16.7.1.5 Vehicle Qualification Test

Testing shall be performed as prescribed in 49 CFR 213.345.

16.7.1.6 High Speed Stability Tests

A locomotive shall be tested up to 135 mph.

16.7.1.7 Propulsion Kinematic Tests

Propulsion kinematic proof of design tests shall be conducted on the first locomotive. A simulated full load shall be used for the tests. These tests shall subject the propulsion systems to the operations required to demonstrate that the systems comply with all requirements of specified in Sections 2.2, 9 and 11.

In addition, the following tests shall be conducted:

- Acceleration tests from 0 to 135 mph.
- Maximum speed tests.

Braking shall be monitored during the propulsion tests to verify that the brake system operates in a consistent and reliable manner. Data recordings for braking shall be available for inspection by SEPTA but need not be included in the test report unless used as a required braking run. To this end, propulsion and braking runs may be combined if they both can be conducted in accordance with the requirements of the Specification.
16.7.1.8 Propulsion EMI Tests
Propulsion system EMI testing shall be conducted according to the procedures in Section 2.6.

Initial qualification test on the first locomotive shall be taken at 25 Hz locations on the SEPTA Railroad Division/Northeast Corridor.

16.7.1.9 Braking Kinematic Tests
Braking kinematic proof of design tests shall be conducted on the first locomotive. These tests shall subject the electric and friction brake systems to the operations required to demonstrate that the systems comply with all requirements of Section 2.2.7. The brake disc, brake pad, brake shoe and wheel temperature shall not exceed the supplier’s working range, defined as that within which the material is capable of meeting the specified performance and tolerances. Successful completion of all of the preceding tests and acceptance of the test results by the Engineer will be required for final approval of the friction brake system.

In all friction brake tests, for each run, wheels and brake discs shall be cooled to a temperature not to exceed 250°F before initiation of any test. The Contractor shall conduct static wheel and disc temperature checks between brake test runs after the wheels and discs have been heated by the friction brakes to verify equal, consistent operation of all brake units.

The following tests shall be conducted:

- Blended full service brake stops from 135, 125, 100, 80, 60, 45, 30, and 20 mph;
- Blended 50% service brake stops from 80 mph;
- Blended minimum service brake stops from 30 mph;
- Friction-only full service brake stops from 125, 100, 80, 60, 45, 30, and 20 mph;
- Friction only 50% service brake stops from 80 mph;
- Friction only minimum service brake stops from 30 mph;
- Emergency stops from 135, 125, 100, 80, 60, 45, 30, and 20 mph.

16.7.1.10 Braking EMI Tests, Electric Brake
Braking system EMI testing shall be conducted according to the procedures in Section 2.6 and for the operating modes of Section 16.7.1.9, above.
16.7.2 Line Clearance Testing
The Pilot Locomotive shall be equipped with feelers or other approved means to simulate the dynamic outline and shall be operated at low speeds through all trackage of the SEPTA Railroad Division to confirm compliance with the requirements of Sections 2.2.2 and 2.2.10.3.

16.7.2.1 Simulated Service Brake Performance Tests
The following tests shall be conducted on the first locomotive to demonstrate compliance with the performance and thermal requirements of Sections 2.0 and 11.0. A simulated Northeast Corridor profile, provided by SEPTA, shall be used.

16.7.2.1.1 Normal Service Brake Test
A locomotive shall be operated in simulated revenue service with the maximum propulsion acceleration rate up to the maximum authorized track speed and full service brake stops, except for normal brake modulation required to position the locomotive at platforms, stopping for one minute at all stations. This test shall be conducted with all propulsion and electric brake systems operating. The train performance shall comply with all specified propulsion, braking, and thermal performance levels.

16.7.2.1.2 Partial Electric/Blended Service Brake Test
A locomotive shall be tested with all conditions as in the Normal Service Brake test of the preceding paragraph except that the locomotive shall have only 50% of its electric brakes operational. Under this condition, the specified performance and thermal requirements shall be met.

16.7.2.1.3 All Friction Normal Service Brake Test
A locomotive with operating propulsion but no operating electric brakes shall be operated with all conditions as in the Normal Service Test defined above. Under this condition, the locomotive shall comply with all specified performance and thermal requirements defined in Section 2.2.7.6.

16.7.2.1.4 All Friction Severe Duty Service Brake Test
A locomotive shall be operated with conditions as specified in Section 16.7.2.1.3 with 15% of the friction brake equipment cut out. Under these conditions the locomotive shall operate in simulated revenue service, with reduced performance if necessary, but all thermal capacity limits must not be exceeded. SEPTA reserves the right to approve the selection of the disabled friction brakes for this test.

16.7.2.2 Wheel Slip/Slide Control Test
One locomotive shall be used to conduct a wheel slip control test. During this test all power and braking modes shall be tested to verify compliance with the requirements of Section 12.8.

To verify the efficiency of the spin-slide system performance defined in Section 12.8, spin and slide efficiency tests shall be conducted on the Pilot Locomotive. The locomotive shall be tested on a designated dry section of track that is reasonably straight and within one percent of level. For each test
series, the train shall make four maximum speed stops, two with blended brake and two with friction-only braking, at five brake rate requests including emergency braking.

The locomotive will be outfitted with a track sprayer system that will spray the rails in front of each truck of the test train. The sprayer will use a mixture of water, windshield washer solution and soap in order to achieve reduced adhesion levels. Test stops shall be repeated, with the mixture composition being varied as necessary, until the test train begins to experience wheel slippage during the maximum speed stops at approximately one-half of the full service blended brake request. This mixture blend shall become the test mixture. Slippery rail stops from the maximum speed and starts from an initial speed shall be conducted using the test mixture. The wheel slide protection system shall effectively protect against wheel flats during the test.

In addition to the instrumentation defined in Section 16.7.1.2, speed and brake cylinder pressure for each axle in the braking vehicles shall be recorded.

### 16.7.2.3 Performance Data

During the course of locomotive proof-of-design testing, the following data shall be recorded/determined/verified, and provided to SEPTA in one separate report within 30 days after completion of the last locomotive proof-of-design test. Where applicable, minimum and maximum values shall be provided.

- Power consumption, power factor, and harmonic generation.
- Traction motor and electrical cabinet temperatures.
- Line voltage tolerance.
- Electromagnetic interference – inductive, conductive, radiated and CSI .
- Electromagnetic field - cab interiors.
- Drag coefficient (coast down test).
- Regenerative braking capability.
- Transformer inrush (25 and 60 Hz).
- Phase break and voltage changeover operation.
- Pantograph uplift and pantograph/catenary interaction
- Immunity to RF from hand held radios
16.7.2.4  Locomotive Compatibility

A functional test shall be conducted to demonstrate compliance with Section 2.2.12.3.

16.7.2.5  Cant Deficiency and Stability Tests

A locomotive shall be tested on approximately six to eight curves on SEPTA routes as referred to in Section 2.2.10 to determine if the safety criteria of Section 2.2.9 have been met. These curves shall be selected by SEPTA, and shall include as a minimum the curves selected for simulation in accordance with the requirements of Section 2.12.10. The curves shall range from short radius and low speed (50-75 mph) to long radius and high speed to 135 mph. Test runs shall start at the currently-authorized cant deficiency and increase, in 5 mph steps, to the maximum safe cant deficiency for the locomotive.

High-speed stability tests shall be performed on tangent track. During these tests, truck-mounted lateral accelerometers shall be monitored for signs of impending vehicle instability. A track perturbation shall be used, with worst case class 6 deviations, to stimulate truck action.

The above test data shall be verified during Corridor tests. In all cases, the official 25 Hz results shall be from the tests in the Corridor.

16.7.3 Instrumented Wheel Sets

Refer to Section 11.16.

16.7.4 Ride Quality

Refer to Section 2.10

To verify conformance to the ride quality requirements of Section 2.10, the Pilot Locomotive shall be subjected to ride quality road tests. As a minimum, the ride quality tests shall consist of operating the locomotive over SEPTA's Railroad Division for a round trip between Suburban Station and Paoli, making all local stops while operating a normal scheduled speed. Instrumentation capable of measuring and charting (for permanent record) the magnitude and frequency of the vertical and lateral shocks expected, up to 1.0g and 0.5 to 50 Hertz, shall be provided and operated by the Contractor, who shall reduce the raw data for presentation to the Engineer. Sensing units shall be located on the locomotive floor above the intersection of the locomotive longitudinal center line and each truck transverse center line. A FFT analyzer shall be used.

In the event that the dynamic behavior of the locomotives is inferior in any respect to the Technical Specification requirements, the Contractor shall submit to the Engineer, within 60 calendar days, a program containing mathematical analysis of the problem and a course of action for its correction. If the Engineer approves the analysis and corrective measures, those corrective measures shall be made effective on the Pilot Locomotive within 90 calendar days at the expense of the Contractor, the locomotive shall be retested, and if the measures are successful, they shall be applied to all the locomotives. If not, the analysis and correction steps shall be repeated, resubmitted and retested until success is attained.
16.7.5 Noise and Vibration

After equipment installation, noise and vibration tests shall be conducted in accordance with 49 CFR 210 on the first locomotive to confirm compliance with the requirements of Section 2.3. Compliance shall be based on measurements taken in essentially a free-field environment such as outdoors, away from any reflecting surfaces other than the ground, ties, and ballast. All measurements shall be made with an ambient sound level of not less than 10 dB below the noise produced by the equipment being measured, using the same scale or octave band.

The interior and exterior noise levels and vibration levels of the Pilot Locomotive shall be measured to prove compliance with the requirements of Sections 2.3 and 5.9. Interior noise measurements shall be made with all vehicle systems operational while operating on level tangent track in an open area, from standstill to 135 miles/hour and back to zero speed using full service braking. The sound level meter shall conform, as a minimum, to the requirements of ANSI S1.4, Type 2, and set to an A-weighted slow response or with an audio dosimeter of equivalent accuracy and precision.

In conducting interior sound level measurements with a sound level meter, the microphone shall be oriented vertically and positioned approximately 15 centimeters from and on axis with a seated engineer’s ear. The assistant engineer’s position shall also be tested. Measurements with an audio dosimeter shall be conducted in accordance with manufacturer's procedures as to microphone placement and orientation.

Measurement of the sound level of the horn shall be made using a sound level meter conforming, at a minimum, to the requirements of ANSI S1.4, Type 2, and set to an A-weighted slow response. While the locomotive is on level tangent track, the microphone shall be positioned 4 feet above the ground at the center line of the track, and shall be oriented with respect to the sound source in accordance with the manufacturer's recommendations. The horn as installed shall comply with the requirements of 49 CFR 229.129. A test of the sound level of the horn shall be accomplished to demonstrate compliance with these requirements.

Vibration tests shall be made with all vehicle subsystems operating, with the locomotive stationary.

The following data shall be recorded:

- Description of noise or vibration source being measured, including pertinent statistical information.
- Description of the environment where the noise or vibration is measured, including a sketch showing source position.
- Operating conditions of noise or vibration source during measurements.
- Pertinent meteorological data.
- Location and orientation of microphones with respect to noise source.
- Description of the equipment used for measurements.
• Instruments settings, corrections, and calibration records.

• Description and measurement of ambient noises.

• Source noise or vibration data obtained, including range of variation.

Tests shall be conducted for cab interior, exterior, stationary, and at speed.

16.7.6 Pantograph

The complete pantograph current collection system shall be tested to verify compliance with the requirements of Section 10.10.1. This shall include a test to verify the force exerted by the pantograph on the catenary wire while stationary and while running in both directions over the complete speed range, up to and including the maximum track speed. This testing shall be performed by the supplier with the full involvement and cooperation of the Contractor.

16.7.7 Communications System Testing

Each component of the communications system, including the GPS and the wireless local area network, shall be tested to verify that they function in accordance with the requirements of Section 13. All equipment which is installed under the Contract on the SEPTA wayside or the SEPTA Control Center shall also be tested to verify compliance.

16.7.8 Engineering Pilot Train Testing

16.7.8.1 General

After the Pilot locomotive has satisfied all applicable on-site testing requirements, it shall be combined to form the Pilot Train and undergo operational, compatibility and coupler tests. Following this, the Pilot Train shall be tested in accordance with the requirements of FRA as detailed in 49 CFR 213.345. The Pilot Train shall be given both Proof-of-Design Shakedown Test and actual revenue service operational tests lasting 6 months. Approved Contractor personnel shall be present on the train for this testing.

16.7.9 Proof-of-Design Shakedown Tests

The first locomotive shall be subject to a shakedown test of 2,500 miles. This test shall be performed after all other proof-of-design tests have been completed. This test shall be conducted in simulated revenue service stopping for one minute at stations. The locomotive shall be operated at maximum performance levels, i.e. full acceleration and full service braking. At each terminal, the operating cabs, pantograph, and direction shall change. The test shall be at a maximum speed of 100 mph and at a maximum cant deficiency of six inches. The profile shall simulate Frazer to West Trenton service.

The vehicles shall be sufficiently instrumented and monitored during these tests to determine that all equipment systems are functioning properly. The instrumentation shall be as defined in Section
16.7.1.2. The same data as defined in Section 17.7.1.3 for the Locomotive performance testing shall be recorded continuously on optical disk. The disks, and all annotated paper chart recordings made during this test, shall become part of the permanent record and turned over to Amtrak with the final test report.

The last 500 miles of the shakedown test must be free any failure of any component or system except for the following, which are specifically exempted:

1. Light bulbs
2. Glazing breakage or scratching caused by outside sources
3. Any component replaced due to normal wear, e.g., brake pads or shoes, pantograph wearstrips, etc.

Locomotives supplied to SEPTA require 500 mile shakedown tests performed; however, these tests shall be on a non-interference basis with revenue traffic. No tests may be performed on these locomotives which shall require tracks to be taken out-of-service or trains to be held clear of adjacent tracks.

### 16.7.10 Actual Revenue Service Tests

The actual revenue service operational testing period shall last 6 months and shall fully test all locomotive mounted components and subsystems in the rigor of simulated or actual revenue operation. The Contractor shall document and report to the Engineer all locomotive defects, operational problems or failures encountered and their remedy, the type and kind of all maintenance performed, any parts used and the cause and remedy of any injury to SEPTA personnel or passengers. This documentation shall include all SEPTA as well as Contractor activities. The purpose of this test is to perform an intensive analysis of the suitability of the design, assembly and materials used on the Pilot Locomotives, with the intent that any changes or modifications found necessary be incorporated into the design of production locomotives prior to their manufacture, reducing or eliminating the need for field modifications after their delivery. The Pilot Locomotive during these tests shall be field modified by the Contractor to completely incorporate all changes found necessary to be made to the production locomotives.

### 16.8 PRODUCTION CONFORMANCE TESTING

#### 16.8.1 General

Production Conformance Testing are those routine and functional tests conducted on every piece of equipment which are used to ensure all equipment produced under this specification is built consistently and operates properly.

All equipment on each locomotive (including the Pilot Locomotive) shall be given tests for proper operation and conformance, at the manufacturer's facility prior to shipment to the Contractor. All equipment shall also be given a functional test (pre-delivery) on the completed locomotive to test for proper operation, by the Contractor prior to issuance of a Release for Shipment document by the Engineer. The test to be performed by each manufacturer and the Contractor on each locomotive
component or subsystem shall be in accordance with the applicable industry standards listed in this Technical Specification and the approved test plan. The following tests in this Section list some but not all of these tests to be performed; all Technical Specification requirements must be achieved in any case. All listed systems shall be subject to Production Conformance testing. Results of all testing shall be provided to SEPTA. The test reports of all tests shall become the property of SEPTA and be included in each Locomotive History book as specified in Section 1.18. This is in addition to, and is not to replace, the Contractor's and suppliers' Quality Assurance Plans.

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16.8.2 Frequency and Application
All equipment on all vehicles shall be subject to the listed tests, as applicable.

16.8.3 Electrical Apparatus Tests
Each component that is separately assembled, housed and wired into a package unit prior to installation shall be tested at its point of manufacture and a certified test report, signed by the responsible Quality Assurance representative of the manufacturer, shall be furnished to the Contractor with a copy to the Engineer. Tests shall be in accordance with IEEE Standard number 11 for DC rotating machinery, number 112 for induction motors and number 16 for control apparatus as appropriate.

16.8.4 HEP and Static Inverters
Each HEP and static inverter shall be tested by the manufacturer in accordance with IEC 61287 to verify compliance with all aspects of the following for the nominal environmental conditions defined in Section 2.2.5:

- All output and control requirements;
- Performance requirements;
- Fault detection and annunciation requirements;
- And isolation requirements.

16.8.5 Inverter Tests
Each propulsion and auxiliary power inverter shall be given a "routine" test by the manufacturer as defined in IEEE Standards number 11, 112 and 16 and IEC 61287 to the applicable standards contained therein as a minimum.

16.8.6 Traction Motor Throttle Controller
With control power connected, each traction motor controller and reverser arrangement shall be tested for correct sequences of operation in both power and braking by operation of the master controller and reversing switch and verification that the function and/or outputs of the various control devices are correct. Proper mechanical interlocking shall also be verified.

16.8.7 Couplers and Draft Gear
Each coupler and draft gear shall be given a test by the manufacturer to demonstrate conformance to the requirements of Section 3.9.
16.8.8 Battery
Each battery shall be given a capacity test at the point of manufacture in accordance with the AAR Mechanical Division Manual of Standards, AAR RP-590 and APTA standard RP-E-007-98R1, using the criteria identified in Section 8.10.

16.8.9 Motors
Each motor shall be given a "routine" test by the manufacturer in accordance with IEC Standard number 349 (11/87 draft) (sections 30.4, 38.3 and 41) as a minimum or their equivalents in IEEE Standard number 112 for AC motors. An alternate testing procedure for the traction motors may be proposed to the Engineer for approval.

16.8.9.1 AC Motors
Each AC motor shall be given a "routine" test by the manufacturer, as specified in IEEE Standard No. 112A for the electrical characteristics and IEEE Standard No. 11 for the mechanical characteristics.

16.8.9.2 DC Motors
Each DC motor shall be given a "routine" test by the manufacturer, as specified in IEEE Standard No. 11.

16.8.9.3 Gear Units
Each traction motor gear unit shall be tested to verify correct manufacturing process. Specific tests shall be developed to demonstrate that gear units comply with current manufacturing and assembly standards.

16.8.10 Heating Components
All heater elements shall be hi-potted by the manufacturer in accordance with IEEE Standard No. 16. The direct current resistance of each heater element shall be within ±10% of the nominal design resistance for that element.

16.8.11 Air Conditioning Components
Prior to shipment to the Contractor, each packaged air conditioning unit shall be tested by the manufacturer by placing the unit in a test chamber where heat load can be applied to both evaporator and condenser coils. The unit shall be operated for at least 8 hours with a clean-up filter-drier in place. Upon test completion, a new running type filter-drier shall be installed.

The unit shall be given a complete functional test to verify refrigerant compressor loading and the control points of all pressure switches and all temperature sensors. Power consumption of all motors, evaporator and condenser fan motor speeds, system pressures and temperatures, and the applied loads to the evaporator and condenser shall be recorded. The unit heat staging, floor/wall heater control output, and the proper functioning of the over temperature protection systems shall also be verified.
Refrigerant and oil samples shall be taken from the first six units following the test completion and analyzed by an independent laboratory to verify the adequacy of the system cleanliness and adequacy of the evacuation/dehydration process. Test results shall comply with the requirements of ARI Standard 700. If the results from first six units are acceptable, a sampling plan of one unit in six shall be employed thereafter.

The manufacturer shall conduct insulation resistance and high potential tests on each unit.

Each refrigerant compressor shall be given an air pressure test. Each evaporator and condenser coil shall be proof pressure tested and each complete unit shall be vacuum tested, leak checked with an electronic sniffer, and pressure tested to ASTM requirements and documented with ASME certificates.

### 16.8.11.1 Air Conditioning

A full functional test of the complete air conditioning system, including temperature controls, of each vehicle shall be conducted.

Controls and dampers shall be verified and adjusted, if necessary, for even air distribution and proper circulation.

The test shall include a "soak" period for a minimum of 1 hour at the specified design ambient conditions. The temperature pull-down time, after the air conditioning equipment is energized, shall conform to results of the test for the particular vehicle type. Internal heat loads shall then be applied such that the air conditioning system achieves and maintains the full cooling operation mode for a minimum of 1 hour. All system operating parameters, including but not limited to the following, shall be recorded during the 1-hour operation:

- Supply HEP voltage,
- All motor currents,
- Condenser fans and evaporator blower’s speed and correct direction of rotation,
- Pressure control devices set points,
- Compressor unloading set points,
- Temperature control switch points,
- Evaporator and condenser plenum pressure.

The following data, as a minimum, shall be recorded at 10-minute intervals throughout the entire test period:

- Re-circulated air inlet Dry and Wet Bulb temperatures,
- Fresh air inlet Dry and Wet Bulb temperatures,
- Condenser air inlet Dry Bulb temperature,
- Vehicle interior Dry Bulb temperature at 9 (total) equally spaced locations along the vehicle at 4 inches and 48 inches at the seating positions, and 67 inches along the center aisle,
- Compressor motor current (3 phases),
- Compressor unloading status,
- Compressor suction and discharge pressures,
- Status of the refrigerant in the sight glass/moisture indicator (presence of bubbles and the moisture indication),
- Refrigerant level in the receiver (if provided).

16.8.12 Air Brake Equipment

16.8.12.1 Air Compressor

Each air compressor shall be given a capacity test and an air output quality test to verify compliance with the requirements of Section 11.4.

16.8.12.2 Air Brake Valves

All valves shall be test rack tested and certified to the latest COT&S per Federal Regulation 49 CFR 229.

16.8.12.3 Air Reservoirs

All reservoirs shall be tested and certified to ASME Requirements for Pressure Vessels.

16.8.13 Truck Tests

The first production truck (including the frame, bolster, and any primary structural members) shall have its fabrication technique qualified by means of a complete inspection of every weld and casting critical area, preferably by radiographic methods; if determined by the Engineer that radiographic methods are not practical for some areas, then the inspection in these areas shall be performed using both ultrasonic and magnetic particle inspection methods approved by the Engineer. Castings shall be radiographed in accordance with Section 15.4.4. Radiographs shall be made in accordance with either American Welding Society (AWS) D1.1 or ASTM E 94. The radiographic inspection quality level shall be selected by the truck manufacturer to be consistent with the truck design, but shall not be of lesser quality than that required by Appendix F of AWS D1.1. If the first truck fails the radiographic/ultrasonic inspection, then the second shall be inspected, and this process shall continue until a truck passes the inspection. The production variables for the succeeding trucks shall duplicate those for the truck which passes the above inspection.
After qualification in accordance with the preceding, all exposed welds and entire castings of all steel castings used for succeeding trucks shall be subjected to magnetic particle or dye penetrant inspection. Magniflux shall use a no-yoke probe only. All critical welds, and critical areas of all castings, shall be inspected using radiographic methods on 15 percent of the trucks, chosen at random by the Engineer. If determined by the Engineer that radiographic methods are not practical, then all critical welds, and critical areas of all castings, shall be inspected on all trucks produced by using both ultrasonic and magnetic particle inspection methods approved by the Engineer. Magnetic particle inspection shall be in accordance with ASTM E 709 or approved equal. Dye penetrant inspection shall be in accordance with ASTM E 165 or approved equal. Critical welds shall be as identified by the truck manufacturer and approved by the Engineer, and shall include, as a minimum, all assembly welds and welds or portions of welds which, based on the results of the stress analysis and/or truck tests, are expected to be critical in fatigue. Critical areas of castings shall be identified in a similar fashion. Critical areas of each truck frame and truck bolster shall be inspected as required by Sections 10 and 15.

**16.8.14 Truck Spin Tests**

Following completion of assembly, each truck shall be elevated off the rail and the traction motors powered to perform a truck spin test. This test shall be performed at a test site near the truck assembly activity using power supply and instrumentation specific to and dedicated to this activity. Axles shall be spun from 0 to 100 miles/hour wheel peripheral speed at 10 miles/hour increments to and from the maximum. Vibration measurements shall be made at each 10 miles/hour speed increment and during 30 minutes operation at 100 miles/hour speed. Bearing temperatures shall be measured at 100 miles/hour speed, and shall be within the bearing manufacturer's specified limits. Vibration measurements shall be within a standard range established by the Contractor and approved by the Engineer. Bearing and gear noises shall be acoustically monitored at all speeds.

**16.8.15 Cab Signal, ATC and SEPTA PTC Equipment**

The Contractor shall develop a factory test plan and factory test procedures in accordance with the requirements listed in Section 13.0 and Section 16.5.18. The tests performed under this test plan shall verify compliance with all requirements of the FRA and AAR.

**16.8.15.1 Test Plan**

The factory test plan shall be submitted for approval a minimum of 6 months prior to the scheduled commencement of manufacturing of cab signal and ACSES equipment. The plan shall identify the in-process testing and inspections to be performed, the final factory tests and inspections, the anticipated schedule for tests and inspections, and the schedule for submittal of detailed procedures. The plan shall describe the scope, method, result, documentation, and facility location of each test and inspection. The plan shall also describe the management control method by which the Contractor proposes to implement and enforce the plan.

**16.8.15.2 Procedures**

Detailed procedures shall be developed by the Contractor for the inspection and test of all replaceable units, major assemblies, and the complete cab signal and ACSES system. The procedures shall be
submitted for approval a minimum of 2 months prior to the scheduled performance of the test or inspection. The procedure shall identify the configuration of the unit, assembly, or system to be tested or inspected; the prerequisites, test equipment required, test set-up, step-by-step instructions with pass/fail criteria, data to be recorded, and all special conditions or facilities required.

If special or non-standard test equipment or fixtures are required, a description of such equipment and instructions for their use shall be included in the procedure or attached thereto.

16.8.15.3 Minimum Test and Inspection Requirements

The following tests and inspections shall be performed:

1. Each replaceable unit shall be 100% mechanically and electrically inspected and functionally tested.

Each major assembly shall be 100% mechanically and electrically inspected and functionally tested.

All cab signal and ACSES equipment shall be functionally tested in a system configuration prior to delivery to the Contractor's facility.

All wiring shall be thoroughly tested to insure exact compliance with the approved circuits. The test shall be designed to detect all wiring faults including errors, extra wires, opens, shorts, and crossed connections.

All equipment shall be assembled into a system configuration, in accordance with (3.) above, and tested for leakage resistance. This test shall verify that the resistance between all circuit elements and all chassis, case, or rack members is greater than 20 megohms at 72 VDC, under any and all humidity conditions.

16.8.16 Seat Tests

Seats shall be tested to verify concurrence to the requirements found in Section 5.7.

Seat cushions selected twice at random by the Engineer during cushion production shall be tested to verify compliance to requirements found within Sections 15.14 and 5.15.9.9.

16.8.17 Main Transformer

16.8.17.1 Transformer

Each main transformer shall be given standard commercial tests by the manufacturer to verify correct manufacturing process. Tests shall be performed in accordance with the appropriate USASI Specifications, including C57.98-1968.

These tests shall also include:
Impulse test;
A basic impulse insulation level (BIL) test shall be made on the first production transformer of all primary windings. The 25,000 volts primary winding configuration shall withstand a 150,000 volts basic impulse level test, and the 11,000 volts primary winding configuration shall withstand a 110,000 volts basic impulse level test. In the event this transformer fails to pass the impulse test, the next three production transformers shall also be given this impulse test. Should failure occur on any of these three transformers, then every transformer produced shall be given and must pass an impulse test.

Resistance Measurements;
Ratio;
Polarity and Phase Relation;
No-Load Losses and Excitation Current;
Impedance Voltage and Load Loss;
Low Frequency Dielectric Test;
Insulation Fluid Leak.

The cable, top termination, and transformer connection shall be supplied as a complete assembly. All assemblies shall be subjected by the manufacturer to a routine overvoltage withstand and partial discharge test.

16.8.17.2 Fan and Pump Motors
The following tests shall be performed by the manufacturer on all fan and pump motors in accordance with IEEE Standard No. 11, where appropriate:

Measure cold resistance of the windings.
Check direction of motor rotation.
Run motors for two hours at rated voltage, recording amperes and watts.
Verify noise and vibration levels.
Measure hot resistance of the windings.
Conduct low frequency dielectric test.

16.8.18 Coupler Leads and Inter-locomotive Jumpers
All leads and jumpers shall be tested at the manufacturers' facility to verify correct pin to pin continuity and to insure that the wiring insulation requirements of Sections 15.23 and 15.23 are met.

### 16.8.19 Communications Systems

All communication systems shall be tested by the manufacturer to verify compliance with the requirements of Section 13. Additionally, the antenna shall be tested for conformance with the specified radiation pattern. Six copies of test sheets, with serial numbers of equipment tested, shall be furnished to SEPTA certifying that the standards listed in Section 13 have been met and that the method of measurement specified in the standards was followed in conducting these tests.

### 16.9 PRE-DELIVERY TESTS

As a minimum, the tests listed in this Section shall be performed on each locomotive (including all Pilot Locomotive) prior to the issuance of a Release for Shipment document by the Engineer. The Contractor's production conformance test shall include all tests and adjustments which can be made prior to delivery in order to keep locomotive acceptance testing and adjustments at SEPTA to a minimum.

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#### 16.9.1 Frequency and Application

All equipment on all vehicles shall be subject to the listed tests, as applicable.

#### 16.9.2 Pipe Pressure Test
After the installation, connection and cleaning of all piping as specified in Section 15.20, the piping shall be pressure tested in accordance with the latest edition of the Code for Pressure Piping, ANSI B31.1. All leaks which appear during pressure testing shall be repaired, after which the system shall be retested until leak-free.

16.9.3 Water-tightness

Water shall be sprayed from nozzles which are spaced no more than three feet from, and aimed directly at, the surface being tested. Not less than 0.625 gallons of water per minute per square foot shall be delivered to the surface being tested, and the nozzle velocity of the water shall be not less than 150 feet per second.

Water for all tests shall be sprayed for a minimum of 10 minutes before the inspection for leaks begins, and shall be sprayed continuously during the inspection.

16.9.3.1 Vehicle

16.9.3.1.1 Locomotive Body

The entire body of each vehicle, including doors, windows, and gangways, shall be given a complete water-tightness test. The test shall be conducted before installation of sound deadening material, thermal insulation, interior finish and panels. All exterior fixtures which affect the watertight integrity of the vehicle, such as windshield wipers, shall be installed prior to the test.

16.9.3.1.2 Locomotive End

The end of each locomotive shall be tested separately to verify water-tightness.

16.9.3.1.3 Equipment Boxes

A water-tightness test shall be conducted on individual under-floor equipment boxes, after installation, to augment the test of each complete locomotive body. During the equipment box water test, the required spray shall be directed to the exposed sides and ends of the boxes as would normally occur during locomotive wash operation or/and as a result of water spray from the wheels. Following the equipment box water spraying, the exterior surfaces of each box shall be wiped out to eliminate the possibility of water entering to the inside when the boxes are opened for inspection. All boxes shall be inspected within 30 minutes of the water spraying. This test shall be considered a failure if any traces of water are found inside the boxes.

16.9.4 Clearance Tests

Each locomotive shall be measured to prove compliance with the Contractor's approved clearance diagram for the as-built locomotive configuration, to verify that the locomotive clearances while in operation will meet the requirements specified in Sections 2.2.2 and 16.6.1. In addition, the centering of the carbody with respect to the trucks shall be measured, and corrected if necessary. The completely
assembled truck shall not exceed the clearance limits specified between the truck and the carbody, and the limits between the truck and the rail as found in 10.2

16.9.5 Lubrication Checks

All lubrication points on the locomotive shall be checked for proper initial lubrication prior to shipment. All gear unit drain and fill plugs shall be wired, and all other fittings checked for proper configuration. Checking shall be followed by paint marking, and shall be recorded with the type of lubricant used in the Locomotive History Book.

16.9.6 Trainline Tests

The Contractor shall verify the accuracy of the electric trainline connections by use of a test panel. The test panel shall use the illumination of lights or other appropriate means to confirm that only the proper trainline wires are energized when the various locomotive controls are operated, and that there are no shorted, crossed, incorrect or open circuits. This test shall exercise the controls in both cabs of the locomotive. All spare trainline circuits shall also be tested.

16.9.7 Communications Systems

Each radio shall be tested and adjusted to meet all technical parameters delineated in Section 13, and the proper certificates supplied in the Locomotive History Book. Additionally, the antenna shall be adjusted for conformance with its specified radiation pattern. The entire communications system and components shall be tested for proper operation. During the testing all functions of the IC, AVL, wireless LAN and all other communications equipment shall be exercised. The Contractor shall provide as approved by the Engineer a suitable simulation of the wayside as necessary to test all communications systems.

16.9.8 Pantograph

The pantograph, main transformer and all high voltage apparatus, including the primary circuit breaker and pneumatic ground switch, shall be tested and adjusted to provide proper operation, including response to fault conditions.

16.9.9 Complete Vehicle Tests

The tests listed in this Section shall be conducted on each locomotive prior to the issuance of a "Certificate of Delivery". The Contractor's production conformance test shall include all tests and adjustments which can be made prior to delivery in order to keep the commissioning testing and adjustments specified in Section 16.8 to a minimum.

16.9.9.1 Locomotive Wiring

These tests shall be made at the Contractor's plant to demonstrate compliance with the requirements of this Section prior to locomotive shipment. When all vehicle wiring is complete, the Contractor shall perform the following tests on each vehicle:
1. Verify all circuits for continuity, proper polarity, and proper connections.

A direct current insulation test shall be made on all vehicles with a DC high-potential tester, measuring current and calculating resistance. The leakage current to ground, and between each major class of vehicle wiring, with all systems connected shall not exceed the following limits:

<table>
<thead>
<tr>
<th>Test Voltage</th>
<th>Vehicle System Voltage</th>
<th>Resistance</th>
<th>Current</th>
</tr>
</thead>
<tbody>
<tr>
<td>500 VDC</td>
<td>below 90 volts</td>
<td>2 megarhms</td>
<td>.00025A</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1000 VDC</td>
<td>90 volts to 600 volts</td>
<td>4 megarhms</td>
<td>.00025A</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1000 VDC</td>
<td>above 600 volts</td>
<td>5 megarhms</td>
<td>.0002A</td>
</tr>
</tbody>
</table>

During this test, all wires within a given class must be jumpered together, either by internal components or by the use of jumper wires. The test shall be made at the Contractor’s plant prior to shipment. The test shall demonstrate compliance with the requirements of Section 15.22.3.

High potential tests shall be conducted after the insulation resistance tests are successfully completed. High potential tests shall be conducted on individual devices, systems, and apparatus, and then on the completed vehicle. Tests shall be conducted to verify the state of the insulation to the case or locomotive body, between wiring of different voltage classes, and between the input and output circuits of high voltage line switches and circuit breakers. Semiconductor devices may be protected against the test voltage by means of shorting jumpers if they are not inherently protected by the circuits in which they are used.

All components and systems shall be in place when the high potential tests are being performed. The Contractor shall jumper together the various wires in a system to insure that all parts of a system are tested, and to prevent capacitive currents or fault currents from passing through and damaging low voltage devices.

On items with double insulation, each level of insulation shall be individually tested.

The test shall be conducted by applying the test voltage listed below for a period of one minute across the insulation being tested. The test is passed if there is no insulation breakdown. The test voltage shall be at a frequency of 60 Hz with a sinusoidal waveform. "V" in the formula below shall be the nominal system voltage for a circuit, in volts DC or volts AC RMS.

<table>
<thead>
<tr>
<th>Nominal Circuit Voltage</th>
<th>Test Voltage, AC RMS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volts DC or AC RMS</td>
<td></td>
</tr>
<tr>
<td>Below 300 volts</td>
<td>2xV + 1000 volts</td>
</tr>
<tr>
<td>300 volts and above</td>
<td>2.25xV + 2000 volts</td>
</tr>
</tbody>
</table>
The test voltage to be used for complete vehicle tests shall be 0.85 times the value defined above for the circuit to be tested.

16.9.10 Monitoring and Diagnostic Systems

All locomotive monitoring and diagnostic systems shall be tested by the manufacturer to verify compliance with the requirements of Section 14.

16.9.10.1 Traction Motor Propulsion Control

With traction power connected, each traction motor controller and reverser shall be tested for correct sequence of operation in both power and braking by operating both the master controller and reverser switch and the onboard diagnostics. With control and pneumatic power connected, all propulsion system hardware shall be tested for correct sequences of operation in all modes by operating the controls in each cab and checking the functioning of the various pieces of apparatus involved. All traction motors and speed sensors shall be tested for proper direction of rotation. Any component that fails to function in the proper sequence shall be repaired and the test repeated until successful before proceeding with other propulsion tests.

16.9.10.2 Friction Brake

The Contractor shall perform a complete functional test of the friction brake system prior to shipment of each locomotive from its plant. Tests shall include, as a minimum, check of command and load weigh signals, brake cylinder pressure settings, control and indicator checks, leakage tests and handbrake test.

16.9.11 Cab Signal, ATC and SEPTA PTC Equipment

16.9.11.1 Test Plan

The Contractor shall submit for approval no later than 6 months after the Date of Award a detailed installation and test plan of cab signal, ATC and SEPTA PTC equipment installation. The plan shall describe the storage and handling of equipment prior to installation, material accountability procedures, installation methodology and sequence, test and inspection points, and configuration documentation procedures.

16.9.11.2 Minimum In-Process Test

Prior to installation of cab signal, ATC and SEPTA PTC equipment, the Contractor shall verify the associated vehicle wiring for accuracy, continuity, and insulation resistance prior to connecting energy-carrying conductors to the cab signal, ATC and SEPTA PTC equipment. Proper polarity and voltage shall be verified.

16.9.11.3 System Test
After installation, a functional system test shall be conducted to verify proper installation and interface. During this test all cab signal, Automatic Train Control, Positive Train Control and event recorder equipment and all interfaces shall be exercised.

This test procedure shall be submitted for approval a minimum of 60 days prior to the scheduled date of the first test. The tests performed under this section shall verify compliance with all requirements of the FRA.

16.9.11.4 Reports and Records

A record of the cab signal, ATC and SEPTA PTC equipment (by serial number) installed in each locomotive shall be made at the time of installation and shall be kept current by the Contractor until the locomotive is accepted. This record shall be a part of the Locomotive History Book. Test reports of all tests conducted, including discrepancies found, corrective action taken, and follow-on action required, shall be made a part of the Locomotive History Book.

16.9.12 Air Conditioning

A full functional test of the complete air conditioning system, including temperature controls, of each vehicle shall be conducted.

Controls and dampers shall be verified and adjusted, if necessary, for even air distribution and proper circulation.

Refrigerant charge and compressor oil levels shall be verified. The initial fine mesh liquid line strainer shall be replaced with the proper mesh at the conclusion of testing.

16.9.13 Heating

The heating system function shall be tested on all vehicles. Test shall include the heating capacity verification along with the thermostatic control operation, which can be combined with the air conditioning production conformance testing of Section 16.8.10 and 16.8.11.

16.9.14 Auxiliary Circuits and Equipment

All auxiliary circuits and equipment shall be verified for proper operation.

16.9.15 Headlights and Marker Lights

The headlights and marker lights on each vehicle, as applicable, shall be aimed and adjusted to meet Federal Regulations 40 CFR 229.125 and 49 CFR 221, respectively.

16.9.16 Interior and Exterior Lights

All interior and exterior lights shall be verified for proper operation including correct lighting load shedding and emergency light operation.
16.9.17 Weighing
The Contractor shall weigh each vehicle at the time of shipment. The weight of each end of the vehicle shall be provided separately. In addition, both trucks of the first locomotive shall be weighed. A weighing device which provides a permanent printed record shall be used and all "weigh tickets" shall be submitted to SEPTA. Copies of the weighing records shall be included in the History Book. The weighing scale shall be maintained within 0.2% accuracy. The Contractor shall submit the scale Calibration Certificate at the beginning of the project and at least once a year over the life of this Contract.

16.9.18 System Functional Verification
After completion of each locomotive, the Contractor shall demonstrate, on 60 Hz input power, that each vehicle subsystem is operational and each cab can properly control a train as required by this Specification. The tests shall be conducted by applying nominal catenary voltage to the locomotive and functionally testing all systems. The Contractor shall develop a check-off list to be used as a guide and a record that all systems has been actuated and have functioned as required.

Particular attention shall be given to assure that the wheel slip/slide correction system is fully operational by simulating an “electronic” slip.

16.9.19 System Inspection List Verification
After completion of each vehicle, the Contractor shall demonstrate that all discrepancies logged against that vehicle during its construction and testing, by either the Contractor's own inspection forces or the SEPTA inspectors, have been suitably resolved to the SEPTA's satisfaction. The Contractor shall submit for approval a control procedure to be employed for tracking of the logged discrepancies. The log and discrepancy tracking sheets shall be available for inspection by SEPTA at all times.

16.10 COMMISSIONING TESTING

16.10.1 General
Commissioning Testing shall be usually conducted on the Railroad where the vehicle is to be operated and is used to demonstrate that the vehicle performs properly in simulated revenue service including operating all vehicle systems. The tests specified in this Section are to be performed by the Contractor on the SEPTA Railroad Division R1 Airport Line, or as otherwise designated by the Engineer. All listed systems shall be subject to Commissioning Testing. The tests shall be satisfactorily completed as a condition of acceptance. Results of all testing shall be provided to SEPTA.

<table>
<thead>
<tr>
<th>Test Description</th>
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<td>Insulation Tests</td>
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<tr>
<td>Functional Tests</td>
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</table>
16.10.2 Frequency and Application

All Commissioning Tests shall be successfully performed once on all locomotives (including the Pilot Locomotive) unless otherwise specified by the Engineer.

16.10.3 Insulation Tests

A direct current insulation test shall be made on each locomotive following the procedure specified in Section 16.9.9.1. All circuits except the transformer primary shall be tested. The test shall show conformance to the values specified in Section 15.22.

16.10.4 Functional Tests

A complete, orderly, and comprehensive test of each and every vehicle system shall be made to verify its proper operation before commencement of test track operation.

16.10.5 Locomotive Body Tests and Adjustments

Truck clearances and the lengths, heights, and locations of electrical jumpers and any other end connection shall be verified.

- Coupler installation shall be verified and adjusted to proper height and level.
- Buffers shall be verified for proper alignment and level.
- Air springs shall be leveled to the accepted design tolerance.

16.10.6 Cab Signal, ATC and SEPTA PTC

The Contractor shall perform a stationary test of the cab signal, ATC and SEPTA PTC system prior to any operation. This test shall conform to all FRA and Railroad requirements for initial and periodic cab signal, ATC and PTC tests. The Contractor shall provide all test equipment, including a cab signal track loop simulator, which is required to properly conduct the stationary test.

Following the stationary test, the cab signal and ACSES apparatus shall be road tested in operation to verify that the systems are calibrated and operating properly. During the road test, all cab signal and ATC functions shall be verified including the overspeed function which shall be verified at each speed command. These tests shall be run with the locomotives instrumented to monitor all of the parameters measured during the locomotive performance tests as described in Section 16.8.15.
16.10.7 Equipment Compatibility Tests

The locomotives shall undergo compatibility tests with other rolling stock including testing in a double-headed consist with two locomotives in the lead position. The locomotive may operate lead (pull) or in trail (push) mode with MU control from a cab car. The locomotive shall be able to operate connected to existing SEPTA rolling stock including Bombardier and Comet cab cars. Depending on SEPTA equipment availability, all consist combinations or variations may not necessarily be performed for each locomotive.

16.10.8 Locomotive Performance Tests

Performance tests shall be conducted by the Contractor according to the procedures outlined in Section 16.7.1 on each locomotive, with the vehicles empty, to demonstrate compliance with the requirements of Sections 2.0, 9.0, and 11.0, and shall be run with the locomotives instrumented as defined in Section 16.7.1.2 for the Locomotive Performance proof of design test. The relationship developed during the Proof-of-Design test in Sections 16.6 and 16.720.4.6, of empty to loaded vehicles, shall be used to evaluate the performance of each locomotive tested without load unless otherwise noted within the sections individual subjects.

16.10.9 Commissioning Shakedown Test

After completion of the testing and adjustment work specified in Section 16.10.9, each locomotive shall be given a shakedown test by the Contractor, with the Contractor's technical representative onboard for 100% of the testing. The shakedown test shall include a minimum of 500 miles. The first 150 miles shall be for the purpose of debugging instrumentation and verification of proper function of all vehicle systems. The next 350 miles shall be fault free, that is, performed with no major system shut downs or faults which would normally cause the train to be removed from or held from revenue service. If the fault free portion of this test is interrupted, SEPTA shall, at its discretion, restart the 350 mile test following the Contractor's approved correction and documentation of the failure. The test shall be conducted in simulated revenue operation with stops at every station. Each cab shall see service as a controlling cab.

16.11 ACCEPTANCE

Successful completion of all tests, including the submission of all test reports, and correction of all known deficiencies by the Contractor and successful retest thereof, shall be accomplished prior to acceptance of a locomotive by SEPTA.

The Pilot Locomotive shall be Provisionally Accepted following completion of the simulated revenue service testing per Section 16.7.2.1. Following completion of actual revenue service testing per Section 16.7.9, and the Contractor fully completing any resulting modifications found necessary, the Pilot Locomotive shall be fully accepted by the Engineer. Upon successful completion of the Production Conformance and Acceptance Tests, and when any additional test conducted by the Engineer as
provided for in Section 17.2 is completed, and upon correction of all known assembly and testing deficiencies by the Contractor, each production locomotive will be Accepted by the Engineer.

**16.12 LOCOMOTIVE RELIABILITY TEST**

The locomotives shall be monitored by the Contractor to demonstrate conformance with the reliability requirements developed in Section 2.7 for a period of 24 months after the acceptance of the last locomotive. On a monthly basis, the Contractor shall issue a report detailing the performance of the locomotive and its equipment with regard to maintenance actions and the calculated mean distance between failures for a six-month moving average.

Any component(s) found to be causing the locomotive or subsystem MDBF to fall below the stated performance level shall be subjected to redesign and modification. The modified vehicle or subsystem shall be monitored for a period of no less than six months or the remaining base time period, whichever is greater.

END OF SECTION