HIGH SPEED ELECTRIC LOCOMOTIVE
TECHNICAL SPECIFICATION

Proposal Copy

HSEL Procurement Program

SEPTA REGIONAL RAIL ENGINEERING

Rev 0, Proposal Copy

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1 SCOPE

These Technical Specifications, including the Contract Drawings, describe and illustrate the criteria to be used for the Contractor's design and construction of High Speed Electric Locomotives, to be operated by the Railroad Division of the Southeastern Pennsylvania Transportation Authority (SEPTA). The locomotives will be operated by SEPTA over the SEPTA Railroad Division and portions of the Amtrak (National Railroad Passenger Corporation) Northeast Corridor line and Harrisburg line.

The locomotives shall comply in all respects with the requirements of the applicable laws and regulations of the United States of America, especially the regulations of the Federal Railroad Administration of the United States Department of Transportation (such as, but not limited to, the Part 200 series of Title 49 of the Code of Federal Regulations), and of the states of Pennsylvania, Delaware and New Jersey, including their respective Public Utility Commissions, in which the locomotives will be operated by SEPTA. Testing will be conducted in full compliance with all FRA requirements. It is noted that while specific agency regulations and recommendations are called for in this Technical Specification, they shall not be considered to be to the exclusion of all others.

This equipment must be built with components that allow for it to safely comply with the Vehicle Track Interaction (VTI) safety thresholds prescribed in title 49, Code of Federal Regulations (CFR) Parts 213.57, 213.333, 213.329 and 213.345 for cant deficiency greater than 3 inches and/or speeds in excess of 90 mph. See also Section 10 Appendix A for additional requirements for vehicle track / vehicle interaction safety limits. Requirements for VTI safety thresholds contained elsewhere in this specification, if found to be more restrictive, shall apply.

Safety, reliability and ease of maintenance shall be the primary design consideration. No component shall require periodic maintenance any more frequently than 184 days nor overhauled more frequently than 4 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 periods of no fewer than 92 days.

The locomotives shall be designed and constructed in compliance with this Specification and the requirements of the following agencies:

a) Federal Railroad Administration (FRA) including but not limited to 49 CFR Parts 223, 224, 229, 231, 232, 236

b) U.S. Department of Transportation (USDOT)

c) U.S. Department of Health and Human Services

d) U.S. Public Health Service (USPHS)

e) The locomotive shall be designed and constructed in compliance with the Standards and recommendations of the Association of American Railroads (AAR).

f) American Passenger Transportation Association (APTA)
g) Environmental Protection Agency (EPA)

Unless otherwise specified, the latest revision of all documents referenced in this Specification as of Notice-to Proceed shall apply. It shall be the responsibility of the Contractor to deliver Electric Locomotives that comply with all applicable laws, rules, and regulations, enacted as of the date of Notice to Proceed.

In case of conflict between requirements, applicable laws, rules, and regulations, unless otherwise specified, the more stringent shall prevail. In case of other conflicts, the Contractor shall report the conflict and request clarification from SEPTA.

The design criteria and constraints that are known to SEPTA have been specified. Further definition and clarification are anticipated during negotiation. If other factors require definition after Contract award, the Contractor shall be responsible for making those definition requirements known to SEPTA in a timely manner for mutual investigation and satisfactory resolution. The Contractor shall not be relieved of the overall responsibility of providing an adequate design for the SEPTA service conditions.

Wherever possible, this Technical Specification has been developed on the basis of the locomotive performance required, rather than specific hardware to be provided. Where specific hardware is mentioned, it is for the purpose of providing an example of concepts or designs acceptable to the Engineer. This approach will allow Proposers to employ innovation and advanced technology where appropriate.

The locomotives designed and built under this Technical Specification shall operate successfully under the environmental, operating and physical conditions listed within these documents. The Contractor's submittals to the Engineer concerning dimensional data, estimated weights, bills of material and other required submittals as specified must be approved prior to construction.

1.1 INTENT

This procurement is for all labor, tooling, materials, parts, training, publications, support, special tools, warranty, spare parts and apparatus required for locomotive construction, use of all facilities needed for locomotive construction, and the actual assembly of the locomotives. This procurement is also for all work needed to obtain tested locomotives, ready for operation when presented for final acceptance. Any items of material or equipment which are not fully described or are omitted in this Specification or the accepted Technical Proposal, but are necessary for the completion of the locomotives, shall be considered a part of the scope of supply.

In this Specification all references to "number of days" shall mean calendar days unless otherwise stated. References to "major systems" shall mean those products which are generically described by the title of any Section of this Technical Specification, and references to "major suppliers" shall mean the suppliers of these major systems.
1.2 DEVELOPMENT

The apparatus and materials shall embody recommended practice, actual experience, compatibility of parts, and shall be of the latest service-tested and service-proven developments that can be incorporated without delaying delivery of the locomotives, unless such delay is approved.

1.2.1 Coordination

The Contractor shall be responsible for system design of the entire locomotive and all of its equipment. The Contractor shall be responsible to SEPTA for proper interrelation, function, and system integration of all phases of all vehicle systems and their interrelation with all other parts of the locomotive and associated support and wayside equipment. Interfaces regarding "outside the locomotive envelope" topics shall be coordinated with the Engineer by the Contractor. Subject areas requiring such interfaces include, but are not limited to, the wayside signal system, cab signal system, Control Center radio system, various communication systems, overhead power supply, maintenance facilities, the locomotive’s RFI and EMI limits, and clearances. This shall include both the SEPTA and Amtrak wayside.

The time system used by all microprocessor equipment on the locomotive, including all event and data recorders, shall be Coordinated Universal Time (UTC). All time displays for the Operator or train crew shall be shown in Eastern Standard Time or Eastern Daylight Savings Time, whichever is appropriate for the given date, in 24 hour clock time. The Contractor is responsible for coordinating this requirement with all suppliers.

1.2.2 Referenced Documents

Various Codes and Standards such as the AAR, APTA, ASME, ASTM, ANSI, IEC and IEEE documents mentioned in this Technical Specification are examples acceptable to the Engineer. Material standards and specifications which are used by the Contractor, unless otherwise approved by the Engineer, shall be of those organizations (such as ASME or ASTM) which are based in the United States, or are generally used on a commercial basis in the United States. The applicable document revision shall be that in effect on the date of Proposal submission. Alternate recognized standards may be suggested by Proposers in their detailed Technical Proposal if submitted with sufficient supporting information to establish equivalency.

Additionally, the specified standards of this Technical Specification may be replaced with Engineer approved equivalent standards proposed by the Contractor after Contract award. The Contractor shall be required to establish the equivalency and to obtain explicit approval from the Engineer for any substituted documents.

1.2.3 Relevant Experience Requirements

Relevant experience with the design and construction of electric locomotive rail equipment, and especially previous experience with the statutory requirements and industry standards which apply to the design and operation of railroad push-pull locomotive equipment in the United States is required. The Proposer must have had previous exposure to the equipment safety standards of the Federal
Railroad Administration including those listed in 49 CFR Part 229 and 238, and familiarity with the American Public Transportation Association’s Passenger Rail Equipment Safety Standards.

1.3 PROJECT IMPLEMENTATION

1.3.1 Submittals

All submittals, except for the cab design mock-up, shall become the property of SEPTA. All submittals shall be made solely by the Contractor through the use of written correspondence describing the purpose of the submittal, the anticipated work and response by the Engineer and the specific identification of the material submitted in terms of drawing/revision numbers, document numbers, etc.

All written communications and submittals unless otherwise noted shall be formatted as typed copy on 8.5 inches wide by 11 inches high paper. Hard copy documents shall be appropriately bound to preclude lost pages while allowing ease of use without special preparation by the Engineer. Documents that can be classified as manuals, reports or analyses shall be fastened on the left side into a profile binder to allow convenient filing. The title of such documents shall appear on the front cover, and shall appear on the spine of the binder if space permits. Electronic versions of submittals and correspondence shall also be submitted in electronic format as required in Section 1.21. All as-built drawings shall comply with the requirements of Section 1.8, and the Contractor shall carefully take these requirements into account when preparing review drawings which will later be part of the as-built drawing package.

Following the Notice to Proceed, the Contractor and the Engineer shall mutually agree on a common correspondence identification coding system. All correspondence shall be coded by the sender with a letter(s) from the English alphabet to designate the originator and with a unique sequence number to ensure unmistaken identity. All correspondence shall readily display the SEPTA purchase order number, denote if a reply is required, and the identity of coded correspondence being replied to, if any. Both parties shall maintain a log to list the date a correspondence is sent or received.

The documentation methodology, particularly as regards to the submission of drawing and engineering changes, shall be user friendly and allow for ease of comprehension and review to the Engineer’s satisfaction. The Contractor shall organize the submissions in a logical, interrelated fashion such that functionally or physically associated subjects are submitted in concert.

All official correspondence shall be submitted electronically in PDF form at a minimum. Information presented by the Contractor for presentations or design review meetings shall be in printed form, at which time the Contractor shall supply sufficient amounts of copies for expected attendance plus one copy in electronic PDF form. The Contractor acknowledges that only drawings, documents, topics or other materials that have been thoroughly reviewed, considered specification compliant and/or are supported by the Contractor shall be communicated to the Engineer to promote concentrated efforts on issues that will benefit and progress the program. To this end, all correspondence shall be retained for a minimum of 5 years to reduce, if not prevent, the needless iteration of work already completed.

Should the Contractor's drawings and schedules be inadequate in the opinion of the Engineer, the Engineer reserves the right to require the Contractor to supply the necessary additional drawings, details and schedules.
After production baseline has been achieved, engineering or manufacturing change orders or deviations shall be submitted to the Engineer for approval as they are issued. The Engineer or his representative(s) shall authorize the Contractor to proceed upon the written approval of drawings provided that the Contractor has notified the Engineer of all deviations. Engineer approval, however, will not relieve the Contractor of his responsibility to fulfill his contractual obligations. The Engineer will supply written reasons and explanations for his disapproval of any required submittals.

Drawings and technical data submittals provided by the Contractor shall be in sequential order consistent with the schedule developed in the Design Review between the Contractor and the Engineer.

The Contractor shall not patent or copyright any original materials or information created by this procurement which will be submitted to either the Engineer or SEPTA, as per Federal procurement regulations.

### 1.3.2 Language

All written communications, submittals, reports, drawings, correspondence and oral communications to the Engineer shall be made in the English language, using American vernacular, and technical terminology conventional to that used in the North American transit industry.

### 1.3.3 Dimensions

All drawings generated in English dimensions need not have metric equivalents. The Contractor shall provide both metric and English dimensioning for his drawings and other communications which are either generated in or use metric. Fractional measurements shall be expressed as a decimal value, and unless otherwise noted and approved drawings shall be made using third angle projections. First angle projection shall be allowed provided all views are labeled, including the front, top, bottom and side views. Within a locomotive subsystem, all dimensions shall be given in either English or English plus metrics. There shall be no mixing of dimension systems on a drawing. Refer to Section 1.8 for additional information.

### 1.3.4 Master Drawing Schedule

If the Contractor is proposing an “as-built” make and model as described in Section 1.2.3, the Contractor shall present their existing drawing tree within 90 days from Notice to Proceed for SEPTA’s review and concurrence. Upon concurrence, SEPTA and the Contractor shall discuss the submittal of drawings during the design review and Pilot locomotive build phases as called out in their individual sections and the final delivery of as-built drawings as referenced in Section 1.16.

Otherwise:

Within 90 days from Notice to Proceed, the Contractor and the Engineer shall jointly agree upon a drawing numbering system not conflicting with other SEPTA drawings to be used for this Contract. All drawing titles shall give full names without punctuation or abbreviations, and should use simple key words to aid in searching. Revision levels should be in letters, not numbers, starting with "A" and be totally compatible with the Contractor’s Configuration Management Plan.
A master drawing schedule format shall then be submitted for review and approval. The master drawing schedule shall list all drawings relative to their hierarchy from general arrangement, though major assemblies, subassemblies - including their associated installations and connections, down to fabricated parts and/or material specifications as outlined in Section 1.8.1. All expected drawings used by major suppliers/sub-suppliers for FAI approvals shall be integrated and reflected in the schedule. The schedule shall also include a listing of all electrical circuit and integrated schematic, pneumatic, and clearance diagrams. The master schedule format shall also include the capability of reflecting submittal and approval status.

Drawing reviews shall be performed for the purpose of approval as directed within three stages as found within the requirements of the Technical Specification. These stages will consist of the Conceptual Design Phase (CDP), Detailed Design Phase (DDP) and the Pilot Locomotive Assembly Phase as described in the Technical Specification.

Thirty days prior to the start of each phase a full update of the master drawing schedule shall be submitted to SEPTA reflecting at a minimum the drawings required for the proposed phase along with any prior phase that might have been reviewed. The master drawing schedule shall grow with each stage with the intent of all drawings being identified by the time of the Pilot Locomotive Assembly phase. The master drawing schedule shall be constantly updated during the Pilot Locomotive Assembly phase with the latest submittal/approval status information and presented formally prior to the start of the Pilot Locomotive FAI.

The master drawing schedule shall have live document status. If any drawing is made obsolete during the life of the Contract, it shall be so listed and identified, along with the identity of any superseding drawing number within the master drawing schedule.

1.3.5 Documents

A standard format shall be used for documentation that is carried throughout the duration of the Contract.

Each document shall, as a minimum, contain the following:

- A title page with a clear and concise title block which includes all pertinent references to the Contract and an accurate description of enclosed information.
- Display approval signatures of the original document on the title page to serve as an easy reminder of the approval signatures required for all future revisions.
- Display the SEPTA purchase order number on the title page.
- Display the originating company’s name and address on the title page.
- Display the overall revision level on the title page and display the varying revision level on each consecutive page.
• Display the unique document number on each page of the document.

• Record the specific changes of a revision on a dedicated page that includes space for new approval signatures for that revision without requiring the removal of previous approval signatures.

• Record the revision levels of individual pages on a dedicated page for verification of proper document composition.

• Contain a table of contents and an itemized listing of tables and figures.

Depending on the type document involved, additional provisions are stipulated in the applicable Section.

Information in the form of foldouts shall not be used. Where information cannot be reduced to the required format size while maintaining legibility of important detail, it shall be divided or formatted appropriately to allow consistent and organized presentations. Except where voluminous information is involved, only one side of the paper shall be used. The use of both sides of the paper shall be restricted to text which allows graphical presentations to stand alone.

As a whole, all documents shall be organized in the order of the following general segments to allow immediate recognition of information as it pertains to the Contract and to the Technical Specification:

• A statement of the purpose of the document, and its relationship to the Technical Specification.

• A summary, if applicable, of results and/or derived conclusions related to each individual provision where more than one is involved.

• Discussion, if applicable, of background information, assumptions and other factors necessary for the understanding of the information provided in the summary, or in the body of information that follows when a summary does not apply.

• The body of the document, which either contains the major and usually more extensive information that supports the summary or details the topics concerned.

• All appendices, providing either background information or a convenient collection of worksheets, drawings, and other reference material.

### 1.4 ENGINEER APPROVAL

During the course of the project the Contractor will be submitting a significant number of items for the Engineer's approval as required by the Contract and Specifications, ranging from drawings and procedures to hardware samples. The "Engineer" is defined as being a SEPTA entity which is primarily the SEPTA Project Manager and/or his designee. The Contractor shall not interpret this process to mean that the Engineer will function as an arm of the Contractor's Project Management or Engineering staff.
Submissions shall be structured to show how the Contractor is responding to the requirements of the specifications, and not on the basis of requiring the Engineer to discover how the Contractor is not meeting those requirements.

All material being submitted shall have been reviewed by qualified Contractor personnel and judged to be suitable for submission prior to doing so, and this shall be so stated in the letter of transmission or on the document, particularly as regards material passed through from subcontractors. Test results shall receive Contractor staff review and signature prior to submission. Submissions found to be deficient with regard to any of the above shall be immediately returned without review to the Contractor.

Submissions shall contain sufficient detail to confirm that specification requirements are being met. However, the Contractor shall use judgment as to what level is appropriate and shall communicate with the Engineer when guidance is needed on a case-by-case basis. Documents with levels of detail and information considered to be beyond what is needed or is time-effective to confirm compliance shall be given cursory review by the Engineer and considered as background information and shall not receive formal approval. Individual submissions shall not contain material from multiple subsystems or subcontractors and such submissions will be returned without review to the Contractor.

Submittals requiring the Engineer's approval prior to implementation shall be reviewed and classified by the Engineer as follows:

<table>
<thead>
<tr>
<th>Classification</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>(A) Approved</td>
<td>The Engineer concurs with the information in its submitted form. The material may be incorporated into the program. An approval shall not be construed as:</td>
</tr>
<tr>
<td></td>
<td>a) Permitting any departure from the Contract requirements; or</td>
</tr>
<tr>
<td></td>
<td>b) Relieving the Contractor of the responsibility for any error including details, dimensions, materials and calculations.</td>
</tr>
<tr>
<td>(B) Conditional</td>
<td>The Engineer conditionally agrees with the submitted information in principle, but insufficient information was provided to allow a complete review, or some details must be revised to make the information fully approved. The material must be resubmitted in revised form for Engineer approval.</td>
</tr>
<tr>
<td></td>
<td>In the case of drawing reviews designated for evaluation during the pilot assembly, drawings may be considered conditional pending verification during the Pilot program at which time any deficiencies shall be reported pending full approval.</td>
</tr>
<tr>
<td>(C) Disapproved</td>
<td>The Engineer does not concur with vital details. The Contractor shall not incorporate the material into the program. The Engineer's objections must be reconciled and the material must be resubmitted in revised form for Engineer approval.</td>
</tr>
</tbody>
</table>
(D) Insufficient Information
The Engineer does not concur due to lack of vital details. The Contractor shall not incorporate the material into the program. *The Engineer’s objections must be reconciled and the material must be resubmitted in revised form for Engineer approval.*

(E) Information Only
Additional information that does not require approval, as determined by the Engineer.

Classification by the Engineer will be assigned within 30 days from the day the submittal is received based on a rate of submittal that is reflective of the pace of an orderly, properly managed program. Priorities will be given to special cases when possible. However, the Contractor shall consider the 30 days criteria and the time requirements involved for mailing when scheduling submittals. The days used by the Engineer in Design Review meetings or in travel to or from such meetings shall not be included in the 30 days figure. Submittals identified as being associated to evaluation phases of the assembly shall be governed by the duration of the phase itself and not the 30 day period.

## 1.5 DESIGN REVIEW PROGRAM

### 1.5.1 General

The Design Review Program is a design development and approval program which shall begin with a Concept Design Phase (CDP) and progress through a Detail Design Phase (DDP). If the Contractor has elected to propose an “as-built” make and model locomotive as defined in Section 1.2.3, all design review subjects will go straight to the detailed design phase where the Contractor shall introduce the system’s information in addition to supplying previously performed acceptance test results.

The Design Review Program shall include, but not be limited to, Engineer review and approval of all the design concept and arrangement drawings of the locomotive, performance and design calculations, locomotive and subsystem configuration drawings and design details, locomotive-body cross section and clearance diagrams, mock-ups, stress analysis reports, tests, publication preparation and locomotive builder's specification.

Design Review activities shall also include review and approval of substitute or equal materials not dealt with in the pre-proposal period, and review and approval of the Contractor’s test program and Quality Assurance program as well as all other Contractor management programs.

Design Review activities shall continue throughout the entire pre-production period, with each succeeding stage presenting greater amounts of detail and reflecting the progress of the designs. In addition to his own designs, the Contractor shall submit the design of all components being purchased by him for review and discussion at the Design Review sessions. In all submissions and at all sessions the Contractor and supplier presentations shall be organized so as to show exactly how the design meets each specific requirement of the Technical Specification.

This program must be completed and all appropriate drawings (entire locomotive design) approved by the Engineer prior to the delivery of hardware. (Loss resulting from deviations from this principle is the
responsibility of the Contractor. The approval of individual releases does not automatically entitle the Contractor to procure hardware.)

1.5.2 Conduct of Conferences
The Engineer shall select the location for the Design Review meetings, which will in general be held in Philadelphia until completion of the mock-ups, and perhaps at the Contractor's facility from that point on at the discretion of the Engineer. The Contractor shall provide SEPTA with at least 21 days notice prior to any meetings or as otherwise agreed.

All reports, correspondence and oral and written communication shall be presented in English. If in the opinion of the Engineer the proficiency of the Contractor's representatives in communicating in the English language is insufficient for efficient exchange of information, the Contractor shall provide a technical interpreter to remedy this situation to the satisfaction of the Engineer at the Contractor's expense.

The responsibility for taking notes at meetings and conferences between the Contractor, Engineer and other participating parties in connection with the design, construction and testing of the locomotives shall rest with the Contractor. The Contractor, after completion of any conference or meeting, will prepare and distribute within 20 days a Minutes of Conference (MOC) which clearly and concisely details the subject matter and the conclusions reached at the conference. Conversely, the Engineer shall within 20 days after receipt of the MOC offer his written concurrence or suggested corrections.

1.5.3 Specification Review Conference
In order to ensure that the Contractor fully understands the detailed intent of the Contract Documents in all areas, the Contractor shall arrange for a series of engineering meetings to be held within 10 days after the Notice to Proceed. These meetings shall be held at the offices of SEPTA in Philadelphia and shall be attended by representatives of the Contractor, major subcontractors, SEPTA and the Engineer. At these meetings the entire technical portion of the Contract Documents shall be reviewed in depth in such a manner as to leave no doubt as to the intent of the Technical Specification in each and every area of design, construction and testing of the locomotives. Minutes of Conference will be prepared by the Contractor covering the meetings which will include each and every understanding and agreement reached and item discussed. After concurrence by all parties, the Minutes of Conference shall become a guiding document in any areas of the Contract Documents where the intent may not be fully clear. No change shall be made to any provision of the Contract during these meetings.

If the Contractor is proposing an “as-built” make and model locomotive as described in Section 1.2.3, implementation of the plan will discussed at this time.

Following the conference, the Contractor's Project Manager, Project Engineer and key engineering staff and the equivalent personnel of each major system supplier shall undergo a 3-day familiarization program on the SEPTA Railroad Division to be conducted by SEPTA personnel. Each individual will be given complete tours on the physical plant, rolling stock, maintenance facilities, Control Center, communications facilities and operational characteristics. The Contractor shall arrange informal nightly meetings to discuss findings during the training.
1.5.4 Scheduling

After the Specification Review Conference, the Contractor shall submit to the Engineer for its approval an outline of the proposed schedule for the entire Design Review Program. All activities comprising this program shall be listed and detailed giving anticipated start and completion dates. The Contractor shall also submit a prospective schedule for all Design Review Meetings. These activities shall be arranged in (but not limited to) the following 4 groupings:

- Locomotive Functional Analysis
- Concept Design Phase
- Detail Design Phase
- Cab Mock-up Construction

Activities within each of these groupings are identified in (but not limited to) Sections 1.5.5, 1.5.6.2 and 1.5.6.3. Mock-up activities shall also be included in this schedule.

1.5.5 Locomotive Functional Analysis

After approval of the minutes of the Specification Review Conference, the Contractor shall submit to the Engineer for approval a locomotive functional analysis. This analysis shall focus on all operational areas with human interface, and shall serve as a working and controlling document for all design activities. Updating of the analysis shall be continual as the design is refined or changed through the Design Review process. It shall define and delineate the following:

a) All normal operating functions and activities. Examples are cab controller manipulations, coupling and uncoupling locomotives, use of public address, use of intercom, train ID, ATC responses, control of doors, etc.

b) Abnormal and failure based functions and activities, including troubleshooting. Samples are failure of brakes to release, failure of propulsion, loss of auxiliary power, dead locomotive rescue, pushing and towing operations, subsystem failure indicators, etc.

The intent of the functional analysis will be to establish exactly how an activity is to be carried out, i.e., what the operating condition requiring action is, what the human inputs will be, how the system will process the inputs, how subsystems will interface and react, and what the final response is to be, both to the user and to the locomotive equipment. Design criteria for the hardware and operational procedures for the user will be evolved, based upon the Technical Specification requirements and meetings with the Engineer. The Contractor is responsible for design and human factors. Procedural information will be the basis for future generation of supporting documents, such as the Operator's Manual.

The analysis document shall contain text, schematics, logic flow diagrams, etc. as appropriate for the relevant subject, shall be formatted for ease of use and reference on a functional basis and shall be kept current by the Contractor with a minimum of time lag, not to exceed 30 days from the date of a change requiring revision.
1.5.6 Design Development Process

1.5.6.1 General

After approval of the locomotive functional analysis, the Design Development process shall commence. This shall be conducted incrementally by the Engineer to evaluate the progress and specification compliance of the selected design approaches and their compatibility with the performance and other requirements of the Technical Specification. Submissions shall be in a format that clearly informs or illustrates how the specification requirements are being met.

Submissions which are judged to give evidence of unsatisfactory design, random or haphazard assembly or require the Engineer to discover what the Contractor is doing will be returned to the Contractor as disapproved.

The Contractor shall plan the Design Development process in two phases. The initial phase will be designated the Concept Design Phase (CDP) and shall be a period during which the Contractor establishes all the basic physical and systems configurations of the locomotives in general arrangement drawing form. Other forms of documentation may accompany these drawings. CDP shall be followed by a Detail Design Phase (DDP) during which the Contractor shall develop all detailed working drawings and documents required for the manufacture of the Locomotives.

At any point during the contract including the design phases where the Contractor or Supplier proposes deviations from the requirements found within the Technical Specification, they must be approved via SCR/SAR processes (as applicable) found in Section 18.3.1.

1.5.6.2 Concept Design Phase

During the Concept Design Phase (CDP) the Contractor shall prepare and issue to the Engineer an advance information a complete series of CDP arrangement drawings of the proposed locomotive design a minimum of 14 days prior to the first review meeting, which shall be the subject of the first series of Design Review meetings.

CDP submittals and activities shall comprise but are not limited to the following:

CPM - The Contractor shall submit a first version of the CPM in accordance with Section 1.9.1 giving particular attention to the entire Design Review Program portions of the procurement. The CPM is to be updated by the Contractor every 30 days.

Master Drawing Schedule – 30 days prior to the CDP the master drawing schedule meeting the requirements of Section 1.3.4 shall be presented for the CDP. All drawings identified for the CDP shall be listed within the schedule as a minimum.

Arrangement Drawings and Related Documents - During CDP arrangement drawings, related documents of the locomotive and all major subsystem hardware items shown below shall be submitted to the Engineer for review and approval Formal approval for the arrangement drawings shall be achieved during the CDP phase.
Drawings shall show at a minimum:

- Dynamic clearance envelope and required wayside clearances
- Location of all doors, access doors and covers in relation to any enclosed equipment.
- Required space for opening of all doors and access doors.
- Location and space requirements for ventilation intake and exhaust openings and cable entrances.
- Location and space requirement for all major equipment.
- Interface drawings for all major components showing overall dimensions, orientation, center of gravity, weight, points of normal support, method of support during mounting and removal and including sufficient information to evaluate access space requirements for maintenance, inspection and repair.
- Truck assembly general arrangement.

Interior general arrangement drawings shall be 1/4-scale transverse cross-sections of the locomotive showing the arrangement of cabs and equipment areas in both longitudinal and transverse views.

All drawings shall be dimensioned using as reference the top of rail, coupler pulling faces and longitudinal center line of the locomotive.

These drawings shall be reissued by the Contractor upon any change to show the current configurations of the locomotive and allow the Contractor and the Engineer to have immediately at hand the latest general arrangements of the locomotive.

**Detailed Technical Specification** - Within 60 days following the start of the Design Review Program, the Contractor shall submit to the Engineer an Interim Detailed Technical Specification covering the methods, materials and arrangements proposed for construction of the Pilot Locomotive. The document shall be similar in style and format to this Technical Specification, which shall take precedence in the event of any differences.

An appendix shall give a complete tabulation of all suppliers and the products they are supplying, and shall also include an update to the Pre-Award Buy America Submittal, indicating any revisions to the manufacturer of goods, country of origin, and cost data.

After approval by the Engineer, it shall be updated by the Contractor every 30 days to continuously represent the current configuration of the details of the locomotive, including all SEPTA authorized Specification changes. A monthly revision sheet shall contain a complete listing of the original and revised text, and details of the approval given by the Engineer. Wherever the original submittal may be lacking information due to unresolved items or methods, this information shall be sent to the Engineer as soon as possible.
Weight Analysis - After receipt of the approved minutes of the Specification Review Conference, and then monthly until the complete weighing of the Pilot Locomotive, the Contractor shall submit to the Engineer a report on the estimated locomotive weight. This shall include the most recent weights for the locomotive without trucks, each truck and the complete locomotive. It shall also include a list of weights for every subsystem on the locomotive, indicating its percentage of the total locomotive weight, and if these subsystem weights are based on actual scale weights of complete equipment. The Contractor shall make scale weighings of all components as early as possible.

Supplier Identification – The Suppliers of all system and major components shall be identified as to their scope of work and products to be supplied. Each Supplier shall identify their own drawing schedule, which will be used for the purpose of approval at the time of their perspective FAI. The Contractor shall be responsible for integration of the Supplier’s drawing schedule into the master drawing schedule and assure all changes in status or revision is maintained.

During the CDP, all Supplier related design and drawing submittals shall be scheduled and FAI target dates and locations set.

Updated Pre-Award Buy America Submittal - The Contractor shall update the Pre-Award Buy America Submittal by documenting any subsequent revisions, including manufacturer of goods, country of origin and cost data, as required in 49 CFR Part 663.25.

1.5.6.3 Detail Design Phase

After the CDP has been progressed to the satisfaction of the Engineer, a Detail Design Phase (DDP) shall be undertaken by the Contractor during which it develops detailed working drawings for all areas of the locomotive based on design arrangements defined during the CDP.

All of these detail drawings must be created or obtained in accordance with an approved drawing schedule (Section 1.3.4), an approved configuration management plan (Section 1.10.1) and formally submitted to the Engineer for evaluation or approval as determined by the Pilot Locomotive design stage.

DDP shall also include Mock-up Construction activities as per Section 1.5.6.5 and material samples preparation as per Section 1.4.

DDP submittals and activities shall comprise but are not limited to the following:

The continuation and updating of all activities specified as ongoing in the CDP - Including but not limited to:

- CPM
- Weight Analysis
- Drawing Schedule
- Detailed Technical Specification
• Locomotive Functional Analysis

• Structural Analysis and Testing

• Arrangement Drawings (continuation)

• Schematics

• Supplier Identification

Detailed Drawings and Related Documents - The Contractor shall submit as a minimum the following detailed drawings and related documents to the Engineer for review and approval/evaluation as described in Section 1.3.1:

1. All top and associated sublevel release drawings, properly dimensioned, detailed, to scale and in accordance with the approved master drawing schedule as per Section 1.3.4

2. All Supplier system/sub system component drawings, packaged by system and component, along with all documentation regarding qualification testing at an FAI level shall be submitted by the Contractor.

3. A full set of structural locomotive body drawings that reflect the full details of construction and Crash Energy Management (CEM) for the purpose of approval upon successful testing as required.

4. A set of preliminary detailed locomotive assembly drawings for the purpose of evaluation during both the DDP and Pilot Locomotive assembly as detailed in Section 1.6.1.

5. Single line control schematic and functional block diagrams for each subsystem, and electrical wiring diagrams and schematics for all electrical and pneumatic circuits. All test points shall be displayed. The functional block diagrams shall identify the "normal" functional paths as well as the functional paths made available through cutouts, bypasses, and redundant circuits. The diagrams shall identify, as a minimum, the "key" hardware that permits safe movement of the locomotive and essential environmental needs of Operator. The functional block diagrams shall display the levels of hardware (as defined in Military Specification MIL-STD-280A) that identify the Lowest Vehicle Replacement Item (LVRI). The format shall be as described in Section 17 for Volume 3 information.

6. A complete set of drawings related to clearance. These shall include static and dynamic envelopes relative to the wayside allowances, including clearances for all parts of the truck, and general arrangement drawings with all static dimensions including camber, low level platforms, high level platforms, curves, etc.

7. Single line piping and flow diagrams for all pneumatic circuits, displaying all valves and control components. All test points shall be displayed, as well as functional paths mentioned in 5, above.
8. Graphs and curves giving response and functional characteristics of the locomotive, subsystems and major items.

9. Manufacturer's data and specification sheets on all control items.

10. Maintenance Allocation Chart that reflects all maintenance requirements and necessary procedures for all equipment in each subsystem. These shall be listed from daily inspection and 92 day inspection to complete overhaul, with frequency and time needed to service being tabulated, and shall highlight all FRA-required inspections.

**Master Test Plan** – A master test plan shall be submitted that shall identify all proof of design testing by both the Contractor and or Suppliers as required in Section 16. The test plan shall identify each test by name, system, location, revision, submittal reference and approval status. All projected target dates for proof of design testing shall be included. Production Testing shall also be included and the test plan used to status the development of the tests.

**Stress Analysis** - A stress analysis of all required areas of the locomotive as per Section 1.5.6.6 shall be submitted to the Engineer for approval.

**Publications and Training Plan** – A comprehensive publications and training plan shall be developed and submitted that reflects the collecting of technical documentation and training programs as information becomes approved under the requirement that all both publications and training must be ready prior to the delivery of the Pilot Locomotive. The plan shall include a schedule that will allow for development of the publications and how they will be used in conjunction with training course outlines. Focus shall be placed upon Operations training, QMP personnel training and running maintenance training.

The plan shall also include illustrated parts catalog, consumable parts list for the support of the locomotives prior to the delivery of production locomotives.

**Mock-up Construction** - Mock-ups shall be prepared as per Section 1.5.6.5 using completed and approved detail design drawings or where required and approved special mock-up drawings. As these mock-ups are progressed and reviewed, feed-forward/ feed-back drawing and mock-up revisions shall take place so that at the end of the DDP all mock-ups are in a finished condition identical with (within agreed upon limitations and parameters) the design of the production locomotives, and all detail drawings are updated to reflect this.

**1.5.6.4 Supplier Certifications**

The Contractor is responsible to secure a certificate from each locomotive subcontractor and supplier that shall be submitted to the Engineer stating that the proposed method of installation, the intended application in service and the maintenance requirements for the material or equipment provided by them. Certifications shall be kept up to date upon the revision Supplier related items.

The certificate shall also include recognition of the requirements of the Technical Specification, including those found in Section 15, Materials and Workmanship and Section 17, Manuals and Training as it relates to their products.
This certification shall be signed by an individual having full authority to commit the subcontractor or supplier to commercial and technical issues relating to the locomotive. The certificate shall also agree that additional maintenance requirements beyond those stated during the Design Review Program shall not be used as a method of correcting a design or manufacturing deficiency in his apparatus discovered before or after the locomotives are placed in service.

Pilot Locomotive construction shall not begin until all supplier certifications have been obtained and submitted to the Engineer.

### 1.5.6.5 Mock Ups

At an appropriate time approved by the Engineer during the DDP prior to the start of construction of the Pilot Locomotive, the Contractor working shall commence construction of a cab mock-up showing arrangements and details, for review and approval by the Engineer.

The mock-ups shall be located at the Contractor’s US final assembly facility, and shall be kept at complete current status, updated as necessary, until the first Pilot Locomotive is completed. Following complete documentation using black and white photographs as specified in Section 1.6.5, the mock-ups or their component parts shall be disassembled and all useful components salvaged, if not defective.

Other than the locomotive structure, the mock-up shall have all components, linings, seating, hardware and equipment similar or identical in appearance to those that are planned for usage on the production locomotives to as great an extent as possible, except as otherwise approved by the Engineer.

The cab mock up shall meet such requirements referenced in Section 5 where mock up confirmations are required and all components shall be displayed in their intended locations so ergonomics can be assessed. Full scale models substituting for proposed hardware may be submitted on a case-by-case basis for approval, except as otherwise required by the Engineer where such a concept is not in his opinion considered feasible.

In the case where the Contractor has already produced a high speed locomotive with the exact layout, and has experienced a full FRA review and approval, the Engineer may, at his discretion, relieve the cab mock up construction requirement if a sample locomotive can be available during the design stage for review and approval purposes.

### 1.5.6.6 Stress Analysis

A complete stress analysis of the locomotive body and trucks shall be performed by the Contractor using an advanced computer-driven finite element analysis such as Nastran, Ansys, Strudl, Algor or approved equal, supplemented as necessary by manual or computerized calculations of stress. The stress analysis shall show the calculated stresses, allowable stresses and margins of safety for all elements at all specified loading conditions, and shall comply with all FRA and APTA requirements and recommendations in accordance with Sections 2.11 and 11.12.

During Design Review the finite element model to be used by the Contractor shall be submitted to the Engineer for approval. The element grid, all assumptions, and all input data, such as loads, section
properties, material properties, etc., shall be included as part of the preliminary submittal, and again as part of the complete analyses. Drawings for both the structure and trucks shall be submitted to totally evaluate connections and stress points involved in the analysis.

Prior to the start of manufacture of locomotive body or truck structural parts, the Contractor shall submit his complete stress analysis report to the Engineer for approval. It shall consist of a complete structural diagram of the locomotive and a complete summary of stress analyses of the locomotive body structure, trucks including axles and major equipment supports to show compliance with the strength requirements of this Technical Specification. A typical stress analysis of any structural element shall consist of a sketch of the element, a statement of the specified applied loadings, a listing of the material of which the element is to be made and its thickness, an identification of critical sections, the calculated stresses at these sections and the corresponding calculated factor of safety in accordance with Section 1.5.6.6. A complete copy of the finite element analysis shall be included with the analysis, with each page numbered and data clearly identified on each page using terms defined in the analysis.

The stress analysis summary shall include a structural diagram of the locomotive body and sheathing showing the location of all elements with their shape, thickness and joining method, along with displays of externally applied loads to the locomotive body. A summary of the calculated stresses in all structural framing members and shear panels shall be given, along with a separate listing of all locations where calculated stress levels approach 12 percent of the criteria specified for various loadings in Section 2.3, as well as the design or operating conditions which precipitated them. A tabulation shall be given of calculated deflections of the locomotive body and the trucks under AW3 load and under the compressive loads listed in Section 2.3.

Analysis shall be made of the coupler attachment to the locomotive body, the truck connection to the locomotive body, torsional loading of the locomotive body from diagonal jacking and torsional loading during normal operation. All critical connections of the locomotive body major structural elements under AW3 loading shall be examined, and a tabulation of the Contractor’s selection of allowable locomotive body and truck fatigue stresses and assumed applied fatigue stress ranges for structural members which are fatigue-critical shall be given.

The Engineer reserves the right to require submittal of relevant detailed stress analysis calculations prior to his approval of production structural drawings if in his opinion the structural adequacy of the proposed construction is questionable.

1.5.6.7 System Component and Material FAIs

All FAIs for system/subsystem components and other parts and materials as listed within the approved FAI schedule shall be performed during the DDP phase. It shall be the responsibility of the Contractor to create and maintain a list of major/subsystem components and an associated schedule for the purpose of creating an FAI status of all subsystems and components. All requirements for FAI activities must be met prior to the commencement of the FAI for the product scheduled. The system/subsystem inspections shall take place at the supplier’s factory before shipment of the equipment. Electrical and pneumatic power shall be applied as appropriate, and the equipment shall be cycled through all modes of operation at a minimum or type testing as required in Section 16.
1.6 PILOT LOCOMOTIVE PROGRAM

Following the successful completion of all design review activities the Contractor shall begin production of a Pilot Locomotive. The Pilot Locomotive shall be considered a "proof of design" first article after being exercised in test and revenue service and the adequacy of all aspects of the design and manufacturing activities have been substantiated. The Pilot Locomotive program shall be conducted in three phases:

1.6.1 Phase 1 – Pilot Locomotive Assembly

The Pilot Locomotive shall be assembled based on design proposals, drawings previously approved during the design phases and the assembly drawings submitted for evaluation.

During the assembly of the Pilot Locomotive, SEPTA Representatives will monitor the build process to evaluate the effectiveness of the configuration and compliance to the materials and workmanship requirements found in Section 15 of the Technical Specification.

The Locomotive Pilot shell shall be treated as a singular, major component with its own design review, assembly evaluation and testing. Drawing approvals shall be achieved as found in Section 1.7.2. General assembly of a full locomotive shall not commence until the structural shell has been provisionally approved.

Installation of all major system, sub-system components and equipment must have an approved FAI status prior to installation. Special care shall be taken in the evaluation of installation and mounting of such system equipment. The Supplier/Sub-Supplier shall be responsible for certification of the installation and integration as detailed in 2.4.6.4 during this period and prior to the Pilot Locomotive FAI.

The Contractor shall closely coordinate with local on-site SEPTA Representatives to assure a thorough review of the Pilot Locomotive assembly is achieved using the proposed assembly drawings. Prior notice shall be given to SEPTA personnel to review any area that will be later covered and inaccessible. Any area mistakenly covered or enclosed shall be re-opened for SEPTA review if deemed necessary by SEPTA at the Contractor’s expense.

Any discrepancy found during the assembly shall be investigated to discover its root cause and appropriate action will be taken to remedy the problem. Issues discovered shall be identified as either Quality or Engineering related. Engineering related issues shall be defined as items in need of change due to fit, form, function, materials, circuitry or software changes where the configuration of the locomotive will change as shown in drawings, schematics or software revision levels. Those deemed as Quality issues shall be tracked and monitored within a separate list, investigated for root cause and quickly corrected during the assembly phase.

All changes to the proposed assembly drawings and schematics shall be recorded within the Pilot Assembly Engineering Comments List (PAECL) maintained within the local SEPTA Field Office as described in Section 1.7.3. Any Technical Specification issues found that that may result in an exception or change of the requirements found within, they shall be handled via the Change process as described in Section 1.8.
All production related testing and additional pre delivery testing as required Section 16 shall be fully pretested during the assembly prior to the Pilot Locomotive FAI. Any changes resulting from testing such as circuit changes, software or test procedural changes shall be handled via the PAECL. Changes shall be made prior to official FAI production testing to allow conformation of changes effectiveness.

1.6.2 Phase 2 – Pilot Locomotive First Article Inspection

The Pilot Locomotive shall undergo a First Article Inspection consisting of a pre-FAI audit, physical inspection and pre-delivery testing to identify the configuration status for the purpose of setting the production baseline. The establishment of this baseline shall occur at the Contractor's facility.

This formal examination shall be gauged against the production drawings, pre-delivery test results, the Technical Specification, Design Review minutes and Engineering Comments List developed during the design and assembly process.

Thirty days prior to the Pilot Locomotive inspections, the Contractor shall submit to the Engineer an engineering data package in sufficient detail to allow the Engineer to compare physical attributes of the locomotives with the engineering documents which describe it. This package shall serve to clarify any discrepancies between the design drawings and the manufacturing process with respect to subassemblies and the packaging of equipment. The package shall contain the following information:

**Drawing Package** - A complete updated master drawing schedule that which includes all drawings by Suppliers and Subcontractors used during system/component FAIs shall be submitted. The schedule must be in hierarchal form as described in Section 1.3.4. All revisions levels must be included and be up to date. Approval status of all drawings requiring full approval during the design reviews and system/component FAIs shall be included. The Contractor shall be responsible for auditing SEPTA’s electronic PDF drawing file collection within the local SEPTA Field Office and provide any drawing files that have not been updated to the latest revision level.

**Subsystem FAI status report** - A subsystem FAI status report must be submitted reflecting the status of all subsystems as having had their initial FAI and presently found to be totally completed or commented upon and awaiting final modifications. Those not totally completed must be accompanied by a list of items yet to be completed and proposed schedule for completion.

**Pilot Assembly Engineering Comments List (PAECL)** – The status of the PAECL shall be audited for closure of all associated items. Any open issues not yet resolved prior to the FAI shall be presented to SEPTA with written commitments as to corrective action plans for each open item prior to presenting the locomotive for its first article inspection.

SEPTA reserves the right to postpone Pilot Locomotive FAI until each of the above mentioned requirements have met SEPTA’s satisfaction.

Upon satisfactory completion of the audit and physical inspection of the Pilot Locomotive, any objectionable issues found either in the physical configuration or that of operation due to circuitry or software shall be recorded and corrective action resulting in changes in drawings, schematics and/or software shall be committed to in writing. Such drawings or schematics that are pending change shall be
highlighted in the master drawing schedule until completion of the change is completed and approved by SEPTA.

Upon the completion of the Pilot Locomotive FAI at the Contractor’s facility and with the update of any addendums, PAEC, test result open issues and master drawing schedule, SEPTA shall determine the status of Pilot Locomotive. Successful completion of this first inspection process will provide the Contractor with provisional approval of the locomotive’s design and assembly level drawings pending any further changes due to post delivery Pilot Locomotive proof of design testing.

The Contractor shall assume the full responsibility, risk, and expense for any procurement or manufacturing action initiated prior to receipt of the Engineer’s approval of the production baseline, and for any subsequent changes made to the production baseline resulting from verifying the vehicles’ capability to meet the requirements of the Technical Specification during the entire Pilot Locomotive and train testing program.

1.6.3 Pilot Locomotive Testing

Upon arrival at SEPTA, the Pilot Locomotive shall be visually inspected for shipping damage and then on-site tested for required functional characteristics.

After visual inspections have been completed, full static commissioning testing shall be performed on the Pilot Locomotive as outlined in Section 16. Upon full completion of the static commissioning testing, the Locomotive shall then undergo a full 92 day inspection.

After the successful completion of the 92 day inspection, proof of performance testing shall commence as outlined within Section 16.

1.6.4 Post-Pilot Program Deliveries

Delivery of any production locomotives shall not commence until the Pilot Locomotive program has been completed and proof that any adjustments/changes found necessary during the Pilot Train program are properly documented and incorporated into the production locomotive configuration. SEPTA reserves the right to disallow shipment authorizations thus restricting delivery until all Pilot Locomotive Program items have been either closed or dispositioned in an agreeable manner to SEPTA.

It is intended that except where otherwise approved or required by the Engineer, the Pilot Locomotive manufacturing quality level shall be the standard for all following locomotives. Each following unit shall be an exact counterpart of the Pilot Locomotive in every material and design respect. In the event that the Engineer discovers any material or design deviation from the approved Pilot Locomotive’s configuration in succeeding production units, the Contractor, unless otherwise approved by the Engineer, shall correct such deviation in all affected production units at no additional cost to SEPTA.

1.6.5 Photographs

The Contractor shall supply to the Engineer by the time of delivery of the Pilot Locomotive one set of un-mounted digital photographs of the locomotive in electronic format and hard copy to further document
the Locomotive’s configuration. The photographs shall be taken by a professional industrial photographer.

The professional digital photographs shall be scaled to print at high resolution on 8 inches by 10 inches paper. All prints shall be printed on a glossy medium with a white border of archival quality. Each photograph shall be arranged by location and subject in a binder using clear sleeves of archival quality plastic suitable for long-term storage of photographic material designed to display each item individually. It shall be possible to easily remove or insert a photograph from the binder. Each photograph shall be captioned with the locomotive identification, Locomotive number and the location in the Locomotive which it depicts on the rear of each photograph.

The photographs shall include side and end elevations in addition to three-quarter views of the exterior and be suitable for use in publicity. These publicity views shall show a locomotive in ready to run condition, with a non-distracting background.

Photographs shall also be made of all individual major structural components such as roofs, sides, end frames and floor structures. The remaining photographs shall consist of the roof exterior and all areas of the locomotive interior, various phases of construction and after all equipment has been installed. A minimum of 75 photographs shall be in the set. In addition, a similar set of professional digital photographs of the mock-ups, shall be provided as defined in Section 1.6.5, containing approximately 40 photographs, shall be sent to the Engineer.

The photographic views shall be approved by the Engineer. All photographs shall become the property of SEPTA.

1.7 DRAWING APPROVAL

Drawing approvals shall be performed using the following milestones to achieve full approval for a production baseline:

1.7.1 Design Phase Drawing Reviews

Unless the Contractor has elected to propose an “as-built” existing make and model locomotive which has been concurred to by SEPTA, drawings as called out in the Conceptual and Detailed Design phase as found in Sections 1.5.6.3 and 1.5.6.3 are required for review.

1.7.2 Pilot Locomotive Assembly Phase Drawing Reviews

Locomotive assembly drawings shall go through an evaluation process during the Pilot Locomotive assembly phase.

It is the responsibility of the Contractor to assure such details contained within the drawings meet the requirements of the Technical Specification. Any changes or exceptions to Technical specification requirements shall be limited to those covered under SCR or SAR approvals as referenced in Section 1.8.3. The Contactor shall bear any schedule delay caused by nonconforming issues discovered.

The Locomotive assembly phase drawing reviews shall be done in two parts:
Structural - The first part shall include the structural drawings provided during the Detailed Design Phase. Detailed part drawings must then be added to the master drawing schedule and provided at the start of assembly. These drawings shall be evaluated during the design phase and the actual assembly of the locomotive to be structurally tested via visual comparison and inspection by SEPTA. Any drawing deficiencies and or objections shall be recorded on the PAECL and immediately corrected prior to testing. Upon the completion or agreed disposition of all design and/or structural testing issues as recognized by SEPTA, the structural drawing package shall be provisionally approved for production of the locomotive shells.

General Locomotive Assembly – General assembly shall be defined as the assembly of a full locomotive, starting with an approved structural shell. 30 days prior to the start of the general Pilot Locomotive assembly, the Contractor shall submit an updated master schedule consisting of all drawings used to build the locomotive. The schedule shall include fabrication parts, assembly and installation drawings and schematics. Copies of all drawings contained in the schedule shall accompany the schedule as defined in Section 1.3.4.

Upon receipt of the schedule and drawings, SEPTA shall commence a drawing evaluation stage where drawings and the product will be evaluated for both execution and compliance to the agreed designs, and Technical Specification requirements via reviews and visual inspections.

During this evaluation, SEPTA shall institute a Pilot Assembly Engineering Comments List (PAECL) as described in Section 1.7.3. Any nonconformance issues found that effect the production baseline drawings shall be added to the PAECL by related drawing number and revision for disposition. The Contractor shall contribute to properly identify any and all applicable drawings that will require change to correct such comments and expeditiously work with the SEPTA Representatives to identify corrective action and revise drawings accordingly prior to the Pilot Locomotive FAI.

Upon successful completion of all open items forthcoming from the design review addendums, system/subcomponent FAIs; Pilot Locomotive FAI, proof of design and performance testing and associated PAECL, SEPTA shall consider all drawings deemed for evaluation to have a provisional approved status and the production baseline set.

After approval of the production baseline, all changes to the locomotive configuration whether mechanically, electrically, software, or test procedures must be handled via the ECP process as described in Section 18.3.3.

1.7.3 Pilot Assembly Engineering Comments List

The Pilot Assembly Engineering Comments List (PAECL) shall be created and maintained by SEPTA at the SEPTA Field Office on the Contractor’s facility. It is meant to be supplemental to any other open items lists from design reviews or Supplier FAIs.

During the Pilot Locomotive assembly, any perceived discrepancy to the locomotive’s configuration in regards to requirements of the Technical Specifications or approved design phase documentation shall be added to this list. It will also include problems with equipment interface or tolerances found during inspection, audits and/or supplemental drawing reviews shall be listed and described in the list. The list
shall also contain proposed corrective action to be filled in during change discussions with the Contractor. Additional columns shall include the governing drawing or document at the time of the listing, including revision level and an associated column denoting document change status and revisions at the time of closure.

The PAECL shall be shared with both the Contractor and SEPTA Project Management upon any changes and/or updates. The intent of the PAECL is meant to be a working document between local SEPTA and the Contractor to track corrective action of issues to the configuration of the locomotive design found during the Pilot Locomotive assembly. Corrective action shall result in the change of controlled documents (drawings, test procedures, etc) under the requirements described in the Changes Section found in 20.6.1.

Upon successful completion of changes to the associated documents and physical verification on the vehicle, SEPTA shall close the associated issue.

### 1.8 DRAWINGS

#### 1.8.1 General

The Contractor shall be responsible for providing drawings for all equipment consisting of structures, all components, assemblies and parts used within the configuration and design of the locomotive by both the Contractor and all Suppliers/Sub-suppliers. The drawing hierarchy scope shall be complete from the top locomotive level basis down to the component’s installation, unit assembly and continue down to the lowest level part or fabrication element. The drawing hierarchy for the locomotive and all components shall be included in the master drawing schedule as described in Section 1.3.4.

Drawings shall be prepared in accordance with ANSI Y14 drawing standards. Individual sheets with a maximum size of 3 feet 8 inches wide by 2 feet 10 inches high shall be used when printed full size, unless otherwise approved by the Engineer. Refer to Section 1.8 for additional details. Drawing number series shall be used as agreed upon with the Engineer and included in the master drawing schedule as required in Section 1.3.4.

Each drawing shall be in an Engineer-approved format and shall be detailed, dimensioned and contain a complete Bill of Material that provides quantities, materials, original component manufacturer name and part number of the actual supplier of the part. Common catalog items shall reflect the material, grade, rating, size, etc. to fully identify the properties of the parts. All drawing dimensions shall meet the requirements and projection views as found in this section and Section 1.3.3.

Until the delivery of “as-built” CAD drawings at the end of the contract, PDF copies of drawings shall be used for submissions and day-to-day use.

All drawings within the master drawing schedule shall be submitted via official contract correspondence that includes a listing of all drawings being submitted by number, name and revision level. Actual individual, softcopy PDF files for each drawing shall accompany the correspondence as attachments with each file named by the drawing number and revision level followed by the contract correspondence.
number in which the drawing was listed within during its submittal to allow automatic sorting within a computer directory.

Distillation settings of the drawings into PDF shall be adjusted and performed using the drawing’s plotter dimension as the paper size to retain full details. Paper copies where required shall be supplied in 11 x 17 tabloid sized paper (or smaller as appropriate) using Acrobat software to fit to page when printing where drawings are needed for design review submittals or presentations. Multiple page drawings may be contained within the individual files. Drawing attachments may be received zip file format, DVD or USB mass storage device sized to hold larger collections.

It is the intent that all drawings required in this section be submitted as outlined in the design phases and or Locomotive Assembly with a full set culminating prior to the Pilot Locomotive FAI in a PDF softcopy formats (softcopy at a minimum, additional hard copies as requested). Official authoring (CAD) file deliveries shall be delivered per Section 1.16 covering As-Built Drawings.

Changes to drawings during the Pilot Locomotive Assembly phase will be controlled via the PAECL as described in Section 1.7.3 until the production baseline has been agreed to formally or provisionally. Any and all changes that result in a drawing change after the baseline has been set (including those that were open items on the PAECL at the time of setting the baseline), the change must be submitted for approval via the Engineering Change Proposal (ECP) procedure as described in Section 1.8.3.

1.8.2 Circuit Diagrams and Integrated Circuit Diagrams

The Contractor shall furnish SEPTA with complete circuit and integrated schematic diagrams of all locomotive electrical, electronic, pneumatic, and hydraulic apparatus, including a full description of each of the components with its value, quality, voltage levels, waveforms, pressures, and tolerances for SEPTA's use in maintenance and repair of the locomotives. Circuit and integrated schematic diagrams will be accompanied by a complete device table and point-to-point wiring list. A narrative shall be included to instruct the user in the use of the documents. Refer to Section 17.2.5, for additional information concerning circuit diagrams and schematic requirements.

Full integrated schematic diagrams for all printed circuit boards shall accompany the locomotive level schematics as a separate appendix. All components on printed circuit boards shall be individually shown in the schematics.

Appropriate test parameters and troubleshooting instructions shall also be furnished for each assembly and sub-assembly based on its associated locomotive system. This information shall be provided in maintenance manuals and training guides.

1.8.3 Changes

1.8.3.1 Technical Specification Changes

During the Design and Pilot Locomotive phases of the contract, discussions may arise where specific Technical Specifications are not being met, however the Contractor feels the spirit of the specification could be made using alternate means or materials. If during the course of these discussions if SEPTA
indicates they will entertain the possibility of change, the Contractor shall be allowed to submit an SCR or SAR, whichever is applicable, for approval:

**Specification Change Request (SCR)** - SCRs are used in the event where specific changes are made to requirements that extend throughout the Technical Specification.

**Specification Adjustment Request (SAR)** - SARs are used when the change is limited to a particular instance only and does not change the basic requirement used throughout the Technical Specification.

The formats for both SCR and SAR proposals shall contain the following information:

- The specific Technical Specification requirement to be changed (in text form)
- Alternate Technical Specification wording for the proposal (SCR) or descriptive instance of the item to be changed (SAR)
- Justification for the proposal
- Technical information attachments as applicable
- Identification of all applicable drawings to be affected by the change.
- Cost, weight, or schedule impact

During the Drawing Review Process, the Contractor shall submit to the Engineer a continually updated list of manufacturing, supplier, interconnection and assembly drawings that would be affected by such changes. Any Technical Specification changes after the Pilot Locomotive baseline has been set, the changes must be submitted via the ECP process found in Section 18.3.3 if the controlled document such as a drawing or procedure is affected.

### 1.8.3.2 Changes to Drawings and Controlled Documents

The Technical Specification, Design Review MOC’s, and the PAECL, in addition to approved drawings and test procedures identify the procurement baseline for the locomotive. Once the baseline has been set and agreed to by SEPTA, all changes to the procurement baseline shall be documented by a change to the controlling document which reflects the baseline requirement in the form of drawings, procedures or software revision levels.

The processing of these changes shall be performed of an Engineering Change Proposal (ECP) in accordance with the procedures described Section 1.8.3.3. All ECPs shall be reviewed by the Contractor’s department responsible for configuration control prior to submittal to the Engineer for review and approval.
1.8.3.3 Engineering Change Proposal

Prior to the setting of the production baseline, the Contractor shall control and maintain an engineering change process that will enable all changes are made to drawings and other controlled documents so they reflect the most up to date revisions.

After the Pilot Locomotive FAI where the production baseline has been set and agreed to, All technical changes shall be proposed in the form of a written Engineering Change Proposal (ECP), which shall be submitted to the Engineer for approval prior to starting any implementation.

A proposed engineering change to any item shall be classified as a major change (within a technical context) whenever one or more of the following areas are affected:

a) Form, fit, function or interchangeability
b) Reliability or maintainability
c) Weight or balance
d) Safety
e) When retrofit is required
f) Sources of repairable and/or replaceable items (source control drawings).

Any engineering change not affecting form, fit, function or interchangeability, nor falling within the preceding definition of a major change, shall be designated as a minor change (within a technical context).

In addition to the revised drawing or procedure, the ECP shall also contain the full details, instructions, tool list for post-production changes, parts list, procedures and drawings necessary for the performance of the work, shall reference all software (publications, drawings, education program, etc.) which must be changed giving the revised information, and also describe any needed revisions or modifications for interim use.

Any Field Modification Instructions (FMI’s) or other documents needed to make the change shall be included in the ECP. The ECP after Engineer approval shall be known as an Engineering Change Notice (ECN).

Any action or cost necessary to correct problems in the product or documentation arising from the Contractor's misclassification shall be borne by the Contractor. The Contractor shall also be responsible for classifying and controlling changes originating from his subcontractors. The Contractor shall submit the ECP to the Engineer accompanied by the technical documentation and the cost information necessary to fully evaluate and approve the change. An ECP shall describe changes to the Technical Specification when applicable, with the inclusion of an approved SCR or SAR as described in Section 1.8.3.

All technical changes that affect safety shall be immediately reported by the Contractor to the Engineer by fax, e-mail, telephone, express mail, in person or by other expeditious means. Technical changes that affect operation shall also be expedited. Both safety related and operational changes are considered to
be Major ECPs. All other technical changes based on production and or material changes will be considered to be Minor ECPs.

The Contractor shall identify the change by ECP number, and if reported verbally shall confirm the change in writing to the Engineer within 2 days. All ECP’s shall be submitted to the Engineer in writing accompanied by all technical information and proposed drawing changes. Every ECN shall identify the locomotives or software involved. Any ECN not performed on every locomotive must include supporting rationale and shall be subject to the Engineer's approval.

Once an ECP has been approved, all ECP information including cover sheets, rationale, updated drawings, and technical information shall be sent to SEPTA via official contract correspondence.

### 1.8.3.4 Accountability

The Contractor shall maintain records such that the configuration of any item being delivered shall be definable in terms of its component part numbers. Differences between the as-built configuration and the release records and documentation shall be known and accounted for, and the status of change approvals and incorporations shall be known and recorded at any point in product development, test, production or operational usage.

A serialization and configuration control record shall be maintained by the Contractor for each vehicle. The Contractor shall make every effort to incorporate changes at the Contractor’s facility prior to shipment. A full configuration report must be delivered to the SEPTA personnel at the SEPTA Field Office located on the Contractor’s facility prior to any final shipment inspections.

If any changes are deemed impossible to complete based on material concerns, SEPTA, at their discretion, may allow shipment with the change as a shipment exception. If the shipment exception is authorized, the Contractor will need to provide information for plans for the change to be retrofitted after delivery or be scheduled in a recognized retrofit campaign agreed to by SEPTA.

The Contractor shall maintain an effective system to track all changes. All retrofit changes shall be recorded on a fleet wise basis as to the vehicles they were installed on in a controlled manner.

### 1.9 PROGRAM MANAGEMENT

The Contractor shall submit to the Engineer for approval within 45 days after the Notice to Proceed a Program Management plan. It shall contain as a minimum an organizational chart providing a definition of personnel responsibilities, the methods and communications to be used to control the program (its schedule, technical performance, program changes, subcontracts, material procurement and field engineering support) and details concerning the Critical Path Method (CPM) scheduling plan for the contract work, as described below.

The Contractor shall organize the conduct of the project in an effective manner. At a minimum there shall be a Project Manager, a Project Engineer and an Assistant Project Engineer as primary staff. The Contractor shall propose selections for approval from a group having considerable pertinent experience in work of the type involved. This primary staff shall have full authority from the Contractor's higher
management to make the final commercial and technical decisions and commitments for this procurement. The Assistant Project Engineer shall have sufficient stature and authority within the organization to represent the Project Engineer, direct the Contractor's field personnel and provide decision-making liaison with the Engineer. The individuals approved for these positions shall not be changed without the approval of the Engineer. The Project Engineer shall insure that any work relating to safety-critical circuits and subsystems is assigned to experienced staff with strengths in this area, and that responsibility is not fragmented.

The Program Management plan shall have a live document status. Any and all changes must be submitted to the Engineer during the next monthly progress report covering the time period the change took place, as referenced in Section 1.8.3. Changes will be subject to approval by the Engineer. Lack of notification or changes deemed compromising the intent of the Technical Specification shall be cause to revoke the approval status of the plan.

### 1.9.1 Critical Path Method Plan

The Contractor shall use an approved state-of-the-art personal computer driven Critical Path Method (CPM) Plan to schedule both its and its subcontractor's and major supplier's work for this Contract. The Contractor shall supply the Engineer with 5 copies (including manuals) of the CPM Plan software and second Plotting software; both licensed under SEPTA's name, with the initial submission of the overall project schedule and maintain them as described in Section 1.21.1. Each submission from the Contractor shall consist of a time scaled network diagram, accompanying computer generated mathematical analysis and a copy of the computer data file. It shall be possible for the Engineer to run the Plan with modified dates to check the Plan's final results.

The CPM Plan shall have a precedence type network, with the start date being the Notice to Proceed, with every milestone listed in the Delivery Schedule provided in the Terms and Conditions being listed, including the delivery of each locomotive. All intermediate milestones shall be shown in proper logical sequence. The CPM Plan shall include all of the Contractor's work activities with sufficient detail such that all interfaces with all direct and related parties of the project are highlighted. The work of subcontractors and suppliers shall be shown on the schedule, being supplied by them and updated whenever necessary. A high priority shall be given to keeping their plans accurate and up-to-date. Major procurement activities shall be indicated, including submittal and approval of shop drawings and delivery of all material. Interruption of service, delivery of equipment, project phasing and any other specification requirements must be included. No schedule activity shall have a duration greater than 30 work days (except procurement lead times). Activities with durations of less than 5 work days shall be held to the absolute minimum. The minimum activity information required in the CPM Plan includes the following:

- A unique work item number for each activity that includes each supplier's identification.
- A concise description of the work represented by the activity in a maximum of 27 spaces.
- A work area code identification in a maximum of 6 spaces.
- Expected activity duration in workdays, based on intended work force.
- Early and late start and finish times calculated according to CPM principles.
The total float shall be indicated for each activity. The critical path shall be indicated on the logic diagram.

Manpower required in average number of men per day.

Activity precedence relationships consistent with proper logic shall be shown with lag codes. The contract milestones and the Contract completion date shall be input as mandatory finish dates and agree with the dates specified in the Contract. Activities shall be described such that the work is readily identifiable for assessment of start and completion. Descriptions shall utilize physical locations such as column lines, stations and elevations where possible to define the work. Activity descriptions of "start", "continue", "completion" or similar will not be allowed. Historical dates for activities shall be used upon the reaching of each milestone for each activity. A revision number and/or date of issue shall identify each updated version of the plan.

Computer produced mathematical analysis calculated according to CPM principles shall accompany the submission of the CPM Plan. They shall include all activities organized in the following activity sorts:

- Activity number.
- Total float, then early start.
- Grouped by subcontractor and supplier responsibility, and then sorted by early start.
- Grouped by area, and then sorted by early start.

The network displayed on the diagram shall depict the exact detail of the CPM network and computer reports. The diagram shall be drawn by using early dates, and shall be time-scaled. The length of the activity representation shall be proportional to the activity duration. The calendar for the network diagram shall be the same as the computer master file. The activity display shall include the activity description, activity number, activity duration, activity total float and the activity subcontractor and supplier code.

The Contractor shall require that his subcontractors and suppliers provide him with the information needed to properly update the Plan, at a maximum period between updates of 30 days, and then pass the updated plan to the Engineer. Particular attention shall be given toward the early detection of any supplier delay, to allow proper response to be made by the Contractor as early as possible.

The activities which are displayed on the network diagram shall be grouped into major components of work as defined by the activity work area coding. The description of these components shall appear on the left-hand side of the plot. The diagram shall be a maximum of "E" drawing size with multiple sheets or long size plotting acceptable, and the vertical distance between activity displays shall be a minimum of 0.5 inch. The critical path shall be identified on the plot. Vertical lines indicating the start and the end of each month or quarter shall be drawn. The date shall be indicated on the plot. This shall be done in the activity display and in the title at the top or bottom of the plot. Completed activities shall be indicated on the plot.

The Contract number and title shall be displayed on the plot. A legend shall be provided which indicates the various symbols used and their meanings. Contract milestones shall be indicated by a prominent
symbol. Different lines shall indicate Critical Path and completed activities. These may include dashed over marking, several line widths or different colors.

The approved diagram shall be mounted on white-faced stiff material suitable for hanging on a wall. The mounting board shall be at least 3 inches larger in length and width than the plot. All other copies shall be unmounted.

Whether or not the CPM Plan is accepted, it shall be updated a maximum of every 30 days, using a Contract skeleton form. The Contract skeleton form is prepared by entering the historical record of actual start and actual or expected finish for activities worked on during the revision period. The number of units in place or percent complete will be indicated for each line item for each reported activity as approved by the Engineer. Revisions to activities not worked on during the period, including changes in duration, or revisions to activity relationship are to be considered logic revisions. If any logic revisions are made, a new computer analysis with the update information and logic changes, and a time-scaled network diagram shall be submitted. A copy of the revised computer master file shall be submitted and shall be accompanied by a letter from the Contractor which explains the revisions. When, in the Engineer’s opinion, the CPM Plan fails to reflect the Contractor's actual plan and method of operation, or the Contractor's completion date as indicated by the CPM Plan is more than one month behind the Contract completion date, the Engineer may require that the Contractor submit for review within 14 days a revised CPM Plan for completion of the remaining work within the Contract completion date. The format shall be as specified above.

1.9.2 Monthly Progress Reports

In addition to the requirement for updated versions of the CPM Plan to be submitted to the Engineer, the Contractor shall submit to the Engineer a Monthly Progress Status Report in the form of updated computer printouts and narrative reports. In the narrative report, the Contractor shall state the percentage of work physically completed and include a description of the physical progress during the report period; plans for the forthcoming report period; problem areas, current and anticipated; delaying factors and their impact; and an explanation of corrective actions taken or proposed. Specifically addressed in the report shall be the status of uncompleted activities which have less than 30 calendar days float and which are either in progress or scheduled to be started within the next reporting period. At the request of the Engineer, the Contractor shall participate in pre-update conferences to verify progress and review modifications to the detailed network schedule prior to the formal monthly submittal. This report shall also include the work done by major suppliers and subcontractors.

1.9.3 Audits

During the evaluation of design, the Engineer will monitor the Contractor's efforts to determine the degree to which the objectives of the Contract are being achieved through the use of reviews and audits. The reviews and audits shall be conducted jointly by the Engineer and the Contractor. In all cases, approval by the Engineer shall not constitute relief from contractual obligations.
1.9.4 Post Delivery Changes

The Contractor shall contain within his Program Management Plan a system to identify, design and install in every locomotive any modifications made necessary by defects discovered during the warranty period of the last locomotive as defined by the warranty category outlined in the Contract. This shall start with the delivery of the Pilot Locomotive, and shall pay particular attention to the outcome and results of the extended Pilot Locomotive testing, as well as later discovered defects on any locomotives. The Configuration Management Plan shall be a part of this effort. A weekly report shall be submitted to the Engineer identifying every defect on each locomotive during the previous week, its resolution and the status of each locomotive involved in any required retrofit, including any necessary changes to publications, drawings or education programs.

1.10 Configuration Management

1.10.1 Plan

It is a basic requirement that the Contractor assures that the configuration of the fleet remains the same for all changes. The Contractor shall develop and submit to the Engineer for approval a Configuration Management Plan within 45 days after the Notice to Proceed. The Plan shall illustrate how the Contractor intends to meet the configuration management requirements and shall include as a minimum:

- Flow charts of paperwork for design changes prior to and following Design Reviews and Drawing Approvals.
- Forms to be used to convey, track and account for the design changes whether approved or not.
- A description of the methods and communications to be used to control hardware configuration identification for purposes of receiving inspection, installation, test, retrofit, reliability, safety and inventory control.
- A description of the forms and methods to reflect the current modification status of every locomotive.
- Detailed processes on how changes are introduced into production of the locomotives and/or delivered vehicles.
- Detailed process of updating spare parts to the latest revision changes.
- Detailed techniques to visually identify component revision level changes to equipment due to modification upgrades and processes to implement such identifiers.
- The method to be used to make required revisions to publications, drawings, education programs, photographs and any other program software.
The Configuration Management plan shall have a live document status. Any and all changes must be submitted to the Engineer during the next monthly progress report covering the time period the change took place, as referenced in Section 1.9.2. Changes will be subject to approval by the Engineer through the ECP process defined in Section 1.8.3. Lack of notification or changes deemed compromising the intent of the Technical Specification shall be cause to revoke the approval status of the plan.

1.10.2 Reports

The Contractor shall submit a report a minimum of every 45 days to the Engineer to reflect the status of documented design changes and retrofits, and to provide a current configuration list of hardware classified as Lowest Vehicle Replacement Items (LVRI) as well as their Next Higher Assemblies (NHA).

1.10.3 Provisions

The Contractor shall maintain accurate and current configuration records which shall be available to the Engineer throughout the period of the Contract and for a 3 year period after final Contract payment. The Contractor shall ensure that his supplier's equipment incorporated in the locomotive design complies with all the related provisions that follow. The guidelines provided by DOD-STD-480A and MIL-STD-483 shall be adapted to the program in a responsible and disciplined manner consistent with good maintenance practices.

1.10.4 Identification

The Contractor's technical documentation shall be capable of defining the approved configuration of hardware and computer software under development, test, production, or in operational use. The technical documentation shall identify the configuration to the lowest level required to ensure repeatable performance, quality, and reliability.

The Contractor's release records and documentation shall indicate the composition of any part number at any level in terms of subordinate part numbers, all Next Higher Assembly (NHA) part numbers of any part and the specification document, specification control drawings or source control drawing numbers associated with any sub-supplier and vendor or Contractor part numbers. This shall apply down to the level at which lower level components are standard and not unique. Such parts shall not be required to have NHA identification.

The Contractor's release records and documentation shall identify engineering changes and retain the record of superseded configuration requirements affecting items which have been formally released for test or production. The Contractor shall employ a system of identifying numbers for specifications, drawings and associated documents which shall ensure that differing parts, assemblies and installations are uniquely identifiable. The Contractor, subcontractors and suppliers shall provide a permanent means of identifying a specific item as having a specific configuration. As a minimum, the items at the lowest level of repair and replacement, as well as their next higher assemblies to the vehicle level, shall be identified in this manner.
All items identified by the same part number shall have the same physical and functional characteristics, shall be equivalent in performance and durability and shall be interchangeable without alteration to themselves or associated items, other than normal field adjustments. An item shall not be considered interchangeable if it requires selection for fit or performance.

The Contractor shall permanently mark as a minimum the items at the lowest level of repair and replacement, as well as the next higher assemblies to the locomotive level. The hardware identification marking shall at all times coincide with the officially released engineering data by revision level.

Serial numbers shall be included on the items and shall be in a unique numerical sequence. Duplicate serial numbers shall not be used within a specific part number. Serial numbers may be alphanumeric and shall not exceed six characters in length to be compatible with SEPTA’s computer reporting system.

All serial numbered equipment that becomes modified through changes must have the revision level of the change reflected in the part number portion of the serial number tag. This tag shall be permanent and easily identifiable.

### 1.11 QUALITY ASSURANCE PROGRAM

#### 1.11.1 Plan

The Contractor shall develop and submit to the Engineer for approval a Quality Assurance Plan for the Contractor and those of all major subcontractors and suppliers at the time of the Design Review. The plan shall illustrate how the Contractor intends to meet the quality assurance requirements of this Technical Specification and shall include as a minimum:

- **a)** An organizational chart, including a definition of the responsibilities of personnel thereon, for receiving inspection, defect material handling (especially related to material found malfunctioning during production conformance testing), production conformance testing verification, process specification implementation, equipment calibrations, etc.

- **b)** The methods and procedures used to control the daily manufacturing processes and material quality.

- **c)** Flow charts of paperwork for the acceptance or rejection of material, for identification and disposition of unacceptable items resulting from inspections, for the specific accountability of material found malfunctioning during production conformance testing, for configuration verification of the constituent locomotive items to be included in the Locomotive History Book, etc.

- **d)** Forms to be used to convey, track and account for design changes implemented in the locomotives regardless of their state of completion and any other forms necessary for the program. Each form shall be serial numbered.
The Quality Assurance plan shall have a live document status. Any and all changes must be submitted to the Engineer during the next monthly progress report covering the time period the change took place, as referenced in Section 1.9.2. Changes affecting the project will be subject to approval by the Engineer. Lack of notification or changes deemed compromising the intent of the Technical Specification shall be cause to revoke the approval status of the plan.

1.11.2 Reports

The Contractor shall submit a report at least every 30 days to the Engineer that shall document the results of audits made within the Contractor's, subcontractors' and suppliers' quality assurance functions; identify unsatisfactory conditions encountered with the design or equipment during its manufacture and/or installation; itemize all Field Modification Instructions (FMI) with a status of their incorporation and cross-referenced to the related Engineering Change Notice (ECN); and identify material part numbers, part designations (if any), serial numbers, configurations and descriptions that were found malfunctioning during production conformance testing. The list shall be cumulative in nature, but shall communicate discernible trends in the increase, stabilization or reduction of conditions encountered. The locomotive number shall be used as a primary means of identification of summary lists of defects, if possible.

1.11.3 Organization

The Contractor and his major subcontractors and suppliers shall establish a quality control program based upon ISO 9001-2008, adapted to the program in an approved manner or an approved equal. The organization of the Contractor's Quality Assurance (QA) Program shall have sufficient, well-defined responsibility and organization. It shall report directly to the General Manager of the Contractor's facility or the Contractor's Project Manager. In any case it must be completely independent of the Contractor's manufacturing or purchasing divisions. The QA personnel shall have complete freedom to identify and evaluate problems; to recommend solutions; to verify implementation of solutions; and to control further processing, delivery, or installation of a nonconforming or deficient item until proper and documented disposition has been obtained.

The QA organization shall be arranged to promote a control function that operates in an independent, objective manner unbiased by schedule, cost, and authority limitations imposed by personnel other than the Contractor's high level management starting with the General Manager or equivalent.

1.11.4 Certification of Personnel

The Contractor's Quality Assurance personnel performing inspections and tests shall be certified for such work. Certification of personnel shall be by the virtue of those skills which are obtained by experience or training and verified by testing. Manufacturing personnel performing special processes, such as welding, brazing, etc. shall be certified for such work. Records of personnel certifications shall be maintained and monitored by the Contractor's Quality Assurance personnel. These records shall be made available to the Engineer for review.
1.11.5 Evidence of Compliance

The Contractor's QA personnel shall maintain objective, verifiable evidence of compliance with the Technical Specification as it pertains to hardware configuration, purchasing, inspecting, handling, assembling, fabricating, production conformance testing, storing, shipping and warranty/repair work in the interest of quality.

1.11.6 Certificate of Compliance

The Contractor may use certificates of compliance for certain materials and products in lieu of the specified sampling and testing procedures as approved by the Engineering for demonstrating proof of compliance of materials delivered to the work. Each shall clearly identify the lot so certified by the certificate and be signed by an authorized representative of the supplier or subcontractor, stating the material complies in all respects with the Contract requirements. Accompanying the certificate of compliance shall be a certified copy of test results or a statement that such test results are on file with the supplier or subcontractor, and will be furnished to the Engineer on request. Each certificate shall contain the information specified for samples, the name and address of the organization performing the tests, the date of the tests and the quantity of materials shipped.

1.11.7 Calibration

The Contractor shall demonstrate an effective time or usage cycled calibration program for testing of measurement equipment and tools. Validity of measurements and tests shall be ensured through the use of suitable inspection, measurement and test equipment of the range and type necessary to determine conformance of items with Contract requirements. At intervals established to ensure continued validity, measuring devices shall be verified or calibrated against certified standards that have a known traceable relationship to the US National Institute of Standards and Technology (NIST) or the local country's similar organization. Tooling used as a media of inspection shall be included in this program. Furthermore, every device so verified shall bear an indication attesting to the current status and showing the date (or other basis) on which inspection or recalibration is next required. Devices suspected of being out of calibration before the stated recalibration date shall be promptly recalibrated. Inspections performed with devices proven to be out of calibration must be re-inspected. All calibration certifications shall be recorded and become part of the Quality Assurance records.

1.11.8 Procedure Documents

The Contractor shall establish and maintain written procedures defining his Quality Assurance Program. The procedures shall encompass all phases of the program to include, but not be limited to, control of subcontractors, receiving inspection, production and process control, functional testing, discrepancy control, measuring and test equipment calibration, configuration control, quality assurance records, shipping inspection and other quality specifications to meet the requirements of the Contract. All such documents shall be made available to the Engineer upon request.
1.11.9 Quality Assurance Activities

The Contractor shall address, as a minimum, the following activities and shall provide a means of self-correcting any shortcomings in his Quality Assurance Program.

1.11.9.1 Procurement

The Contractor shall document in writing the methods to be used for the selection and control of suppliers. These methods shall identify a means of:

a) Selecting qualified procurement sources through the evaluation and assessment of their Quality Assurance programs.

b) Communicating and approving all product quality requirements and changes thereof.

c) Monitoring the supplier's quality performance through the evaluation of procured items against purchase order requirements and through audits.

d) Providing for early and effective information feedback and correction of non conformances, especially of items found malfunctioning during production conformance testing.

e) Approving special processes.

The Contractor shall require each supplier to be responsible for maintaining and retaining records. Furthermore, the Contractor shall require each supplier, as a minimum, to submit with each shipment appropriate certifications, final inspection results and test results. Requirements shall be included for chemical or physical testing records in connection with the purchase of raw materials by the subcontractors. The Contractor's purchase orders shall contain a requirement for the supplier to notify and obtain approval from the Contractor of changes of design of the products which affect fit, form or function, or substitution of materials.

1.11.9.2 Manufacturing Inspection

Inspection shall occur at appropriate points in the manufacturing sequence to ensure quality consideration for compliance with drawings, test specifications, process specifications and quality standards. The Engineer may designate inspection hold points into the Contractor's manufacturing or inspection planning upon review of the Contractor's efforts. Inspection shall be 100 percent, or upon prior approval a statistical sampling plan may be used. Non-conforming materials shall be identified as discrepant, and shall be segregated and reviewed for disposition.

1.11.9.3 Production of Conformance Testing

The Contractor's Quality Assurance personnel shall witness the performance of all Production Conformance tests (see Section 16) and verify proper configuration of the equipment tested. If any item
does not satisfy all performance or design criteria, the item shall be retested until the tests are passed with the necessary adjustments or repairs documented and certified by a witness. In the case of subsystem and vehicle tests, the Engineer's Representative shall be included in this process and concurrence shall be obtained as a permanent part of the certification.

1.11.9.4 Receiving Inspection

The Contractor's receiving inspection activity shall provide for the inspection of all incoming materials. These inspection measures shall be used to preclude the use of incorrect or discrepant materials and to ensure that only correct and accepted items are used and installed. Upon prior approval from the Engineer, statistical sampling may be used. All material certifications and test reports used as the basis for acceptance by the Contractor shall be preserved. Inspection measures shall identify any item at any stage of production to an applicable drawing, specification or other pertinent technical document. Permanent physical identification shall be used to the maximum extent possible.

1.11.9.5 Shipping Inspection

The Contractor's Quality Assurance Program shall provide and enforce procedures for the proper inspection of all products to assure completion and conformance as required by the Contract prior to shipment. The Contractor QA shall be responsible for the collection, verification and submission to SEPTA a full accountability of the configuration as reflected in as built drawings, applied ECNs and test status of each locomotive prior to presentation to SEPTA for shipment inspections. All shipments shall be prepared as required to preclude damage during shipment. The inspections and preparation for shipment shall be verified by the Contractor's Quality Control personnel. The authorization for the delivery of the locomotive shall be approved by the Engineer.

1.11.9.6 Statistical Sampling.

Statistical quality assurance sampling per ANSI/ASQC Z1.4 -2003 used in inspection shall be fully documented and based on generally recognized and accepted statistical quality assurance practices. Prior to the use of statistical sampling, the Contractor shall submit the proposed statistical sampling plan to the Engineer for approval. Sampling plans may be used when tests are destructive, or when quality trend data, inherent characteristics of the product or the noncritical application of the product indicate that a reduction in testing or inspection can be achieved without jeopardizing quality. Any sampling plan used shall provide valid confidence and quality levels, and shall be approved by the Engineer.

1.11.9.7 Changes

The Contractor shall ensure that inspection and tests are based on the latest approved revision or change to drawings and specifications. A procedure shall be maintained that embraces the adequacy, completeness and updating of drawings, and the control of changes. This procedure shall be in coordination with the change control system as provided in Section 1.8.3. The Contractor shall ensure that requirements for the effectivity point of changes are met and that obsolete drawings and change requirements are promptly removed from all points of issue and use. Means of recording the effective points shall be employed and made available to the Engineer.
The Quality Assurance Program shall ensure that there is complete compliance with Contract requirements for proposing, approving and effecting engineering changes. The Contractor’s responsibility for drawings and changes shall extend to the drawings and changes provided by the suppliers for the Contract.

### 1.11.9.8 Identification of Status

The Contractor shall maintain a system for identifying the progressive inspection status of materials, components, sub assemblies and assemblies as to their acceptance, rejection or non inspection. The system shall provide for ensuring that required inspections and tests are performed and that the status of items with regard to inspections and test performance is known throughout manufacturing, installation and testing. Nonconforming items shall be identified by physical segregation and status indicators such as tags, serialization, markings, stamps and inspection records. The identification system shall ensure that only items that have passed the required inspection and tests are used or installed.

### 1.11.9.9 Handling

The Contractor’s Quality Assurance Program shall provide for adequate surveillance work and inspection instructions for the handling, storing, preserving, packaging, marking and shipping to protect the quality of products as required by the Contract.

### 1.11.9.10 Nonconformance

The Contractor shall establish and maintain an effective and positive system for controlling nonconforming material and workmanship, including procedures for its identification, segregation and disposition. Dispositions allowing the use or repair of nonconforming material or workmanship shall require the Engineer’s approval. All nonconforming issues shall be positively identified to prevent unauthorized use, shipment or intermingling with conforming material. Holding areas and procedures mutually agreeable to the Contractor and the Engineer shall be established by the Contractor.

Corrective action and related information shall be documented and made available to the Engineer upon request. Corrective action shall extend to the performance of all subsuppliers and include as a minimum:

- a) Analysis of data and examination of discrepant products to determine extent and causes with corrective action implemented in an expeditious manner prior the next shipment, order or inspection.

- b) Introduction of required improvements and corrections, initial review of the adequacy of such measures, and monitoring of the effectiveness of corrective action taken.

- c) Analysis of trends in processes or performance of work to prevent nonconforming products.
1.11.9.11 Quality Assurance Review

At his discretion, the Engineer will review the Contractor's Quality Assurance Program and its functions to determine compliance with the approved Quality Assurance Plan. During its initial review, the Engineer will inspect the various manufacturers’, subcontractors' and suppliers' Quality Assurance functions. Subsequent examinations shall be performed by the Contractor for the same purpose. The Contractor will be notified of all non-conformance determined during the review. Non-conformance with any part of the approved Quality Assurance Plan may be cause for rejection of the Contract work being performed by the responsible entity (i.e., if the Contractor is responsible, the work on the Contract may be rejected. If a subcontractor or supplier is responsible, the work by that subcontractor or supplier may be rejected).

Whenever the Engineer determines a non-conformance condition with the Quality Assurance Plan (whether in the Contractor's own plan, or that of its subcontractors or suppliers) the Contractor shall promptly correct the non-conformance and request approval by the Engineer. Any schedule delays caused by non-conformance with the approved Quality Assurance Plan, whether on the part of the Contractor or its subcontractors or suppliers, shall not serve as a basis for an extension of the Contract time requirements.

Quality Assurance reviews of the Contractor's, subcontractor's and supplier's efforts shall be made by Contractor QA personnel and may be witnessed by the Engineer. As a minimum requirement, the reviews shall be made as a condition of a subcontract or purchase order prior to the start of any work by a subcontractor, and also within a 30 day period prior to the formal acceptance by the Contractor of the first article inspection or the services being supplied by the subcontractor or supplier.

The Contractor shall prepare a report for each review conducted by it and shall submit a copy to the inspected organization. The Engineer shall be informed of each review. The report will describe the scope of the review, the procedures followed in conducting the review, a statement of all deficiencies found and keyed to the approved Quality Assurance Plan, the corrective action required for each deficiency found, and the date by which corrective action is required.

1.11.9.12 First Article Inspections

The Contractor's Quality Assurance program shall include a procedure for conducting First Article Inspections (FAI). Successful conduct of an FAI shall precede any shipment of material by a subcontractor. FAIs shall be conducted on all parts, subassemblies and assemblies as reflected within the different levels of drawings and prints and/or schematics. All parts and assemblies manufactured by subcontractors shall have an FAI performed. The procedure shall include the following requirements as a minimum:

a) A tracking system shall be developed and maintained which will identify each FAI subject and accurately reflect the present status of each inspection.

b) FAIs shall be performed on an actual sample considered to be complete by the manufacturer and reflecting the approved baseline drawings. Successful completion of engineering tests (see Section 16) for the subsystem is a prerequisite for conducting the FAI.
c) The FAI shall be performed using the approved baseline drawings in conjunction with the Technical Specification reflecting specific requirements of the subject along with any special tools and/or equipment needed to verify the design requirements, configuration and operation (if applicable) of the item being inspected.

d) All technical data required for maintenance manuals and or parts catalogs shall be submitted as initial drafts in authoring file and PDF file formats per Section 17 prior to the full acceptance of the FAI. The initial drafts shall contain sufficient information to adequately maintain the equipment during the Pilot program and initial production locomotive delivery.

e) The Engineer shall be given notice of an upcoming FAI at least two weeks before its schedule date.

1.12 PERFORMANCE OF THE WORK

1.12.1 Contractor’s Responsibility

Performance of the work under this Contract shall be done in strict conformance with the Contract Documents, and consistent with the highest past practices of the Contractor and the North American rail equipment construction industry for the manufacture and assembly of locomotives and their component parts, whether or not expressly set forth herein. The Contractor alone shall at all times be responsible for the adequacy, efficiency and sufficiency of their plant, equipment and employees and those of his subcontractors and suppliers, and shall have the ultimate responsibility for the methods used for the manufacturing and assembling of the items of material or equipment being furnished, and shall maintain records of all engineering changes.

To insure that ordered material meets Technical Specification requirements, the Contractor shall forward to the Engineer a copy of all Purchase Orders or changes in existing purchase orders issued (with price data omitted), giving a complete bill of material description of the material ordered, that are placed to obtain material from any major supplier or to obtain equipment which is specifically identified in the Technical Specification by brand or model number, or for certain components identified previously by the Engineer. All equipment specifically identified in the Technical Specification (or its Engineer approved equal) must be so identified by brand or model number on relevant purchase orders, even when it would be included within a major supplier's complete system.

The Contractor shall take full responsibility in assuring that the Purchase Orders reflect conditions where all Suppliers for parts, components and services meet the terms and requirements of the Technical Specification in regards to design, materials and workmanship (as applicable) in addition to ancillary items such as participation in manuals and training.

Each major supplier (those whose equipment is generically described by the title of a Section of the Technical Specification including seating supplier) selected by the Contractor shall appoint a Program Manager and a Product Engineer to be responsible for their respective products. They shall be the prime supplier contacts for the Contractor (and through him to the Engineer), and shall attend all design
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High Speed Locomotive Technical Specification

SCOPE

review meetings for which their products are involved. They shall coordinate first article inspections, all tests and all Design Reviews of their products. The Program Manager and the Product Engineer shall have ready access to and full authority to commit the supplier to commercial and technical issues relating to the construction of the locomotives and components.

The Contractor and his subcontractors and suppliers shall make use of commercial industry standards and codes (i.e., ANSI, ASME, ASTM, NFPA, SAE, etc.) to the greatest extent possible in their designs of material or equipment under this Contract. Where the Contractor or his subcontractors and suppliers do not utilize such commercial industry standards and codes, but, rather utilize their own standards or specifications, they shall be prepared at the request of the Engineer to demonstrate that their own standards or specifications are equal to or surpass the commercial equivalents. When requested, such information will be considered confidential.

Whenever the Contractor or a manufacturer refers to a material or process by his own specification number, he shall also list the commercial equivalent. If there is no commercial equivalent, he shall provide the Engineer with copies of his own specification, which will be considered confidential in nature.

1.12.2 Design Responsibility

The Contractor shall be responsible for the detailed design of the locomotives and their component parts, and shall prepare all necessary detail drawings and schedules for the Engineer's approval prior to assembly of any items of material or equipment. Consequently, the Contractor or subcontractors shall not deviate in their material or equipment purchasing from the approved drawings and schedules. SEPTA shall not be liable for any additional costs or delays caused by the Contractor's failure to secure the prior approval of the Engineer where required by the Contract Documents.

The Contractor, as part of its responsibility for system design of the entire locomotive and all of its equipment, shall be responsible for the proper interrelation, function and system integration of all phases of all vehicle systems, their interrelation with all other parts of the locomotive, and their interrelation with the wayside and shop facilities, during the design, manufacturing and testing phases of the Contract. The Contractor shall provide the services of a full-time Systems Integrator and shall be responsible for coordinating all electrical and mechanical interfaces between the different vehicle subsystems, the vehicle and the wayside and shop, and electrical interference control.

1.12.3 Manufacturer's Duties

The Contractor shall require that each manufacturer of components, apparatus or parts shall make, assemble and completely test, ready for installation by the Contractor, the component or apparatus to be furnished by said manufacturer as per the Contractor's instructions.

The Contractor shall ensure that all locomotives are identical in all respects except as otherwise agreed to by the Engineer. The Contractor shall ensure that all the material produced by all subcontractors is in accordance with approved drawings and identical throughout the production run, except as otherwise agreed in order to implement modifications and improvements which will be retrofit on earlier production.
1.12.4 Cooperation
The Contractor shall require that all subcontractors, suppliers and manufacturers of all materials, apparatus and parts shall cooperate to the fullest extent during design, construction and testing to ensure proper use or installation of their products. The integrated performance of all equipment within the locomotive is required. The subcontractors shall give prompt notice to the Contractor if the use or installation proposed by the Contractor is not satisfactory to them. No agreement with respect to the above shall be made without a conference at which the Engineer and the Contractor are each represented. The Contractor shall ensure that each major supplier is provided with an updated complete copy of these Contract Documents.

1.12.5 General Workmanship
Whenever under the Contract Documents it is provided that the Contractor shall furnish materials or manufactured articles or that he shall do work for which no detailed specifications are set forth within said Documents, the materials or manufactured articles shall be of the best grade in quality and workmanship obtainable within the market from firms of established good reputation; or, if not ordinarily carried in stock, shall conform to the usual standards for first class materials or articles of the kind required with due consideration of the use to which they will be put. In general, the work performed shall be in full conformity and harmony with the intent to secure the best standards in the work as a whole or in part.

The work performed by the Contractor and all subcontractors shall be executed in conformity with the best accepted standard practice of the trade so as to contribute to maximum efficiency of operation of the material and equipment purchased, accessibility of all parts and components, a pleasing appearance of the material and equipment, and minimum cost of maintenance.

Whenever it is necessary for whatever reason for the Contractor to modify a part used on the locomotive or in any spare parts following the shipment of the Pilot Locomotive, the Contractor shall undertake a retrofit program at his own expense to modify all locomotives and spare parts as necessary so that each similar part has an identical part number, is interchangeable, requires the same troubleshooting procedures and levels of maintenance and performs identically. The Engineer may waive this requirement on an individual case basis.

1.12.6 Substitution of Materials
Whenever items of equipment and/or materials are specifically identified in the Technical Specification by using the name of a proprietary product or of a particular manufacturer or vendor, any material or article which will, in the opinion of the Engineer, perform interchangeably the duties imposed by the general design, including its life cycle costs, will be considered equal and satisfactory, provided the material or article so proposed is of equal substance and function in the Engineer's opinion. Written approval of the Engineer is required for any substitution.

Any request for the use of a substitute or an alternate to the items specified in these Contract Documents must be submitted in writing to the Engineer. It must be accompanied by full descriptive and technical data on the material or equipment proposed, as well as a complete analysis showing that the
substitute's maintainability, reliability and life-cycle costs are equal or superior to that of the product listed in the Technical Specification.

1.12.7 Defective Workmanship or Materials

Whenever the Engineer determines that any of the work being done under the Contract, or that the kind or quality of materials supplied in connection therewith, are not fully and completely in accordance with any requirement of the Technical Specification, the Engineer shall give notice of such noncompliance to the Contractor in writing, and the Contractor shall immediately upon receipt of such notice do all things required to remedy such noncompliance. This does not relieve the Contractor from having and enforcing his own Quality Assurance Program.

1.12.8 Furnishing of Warranty Parts

The Contractor has sole responsibility under this Contract to maintain sufficient warranty spare parts in his stock to support the warranty period requirements. SEPTA is under no obligation to provide spare parts to the Contractor for warranty purposes. The Contractor shall keep on-site at the SEPTA Frazer Shop, or other location on the SEPTA Railroad Division so designated by the Engineer, a sufficient quantity of spare parts to expedite the repair and return of locomotives to service.

In the event that the Contractor does not have needed warranty spare parts on hand, SEPTA, on an individual item basis and in kinds and amounts solely within its discretion, may permit its spare parts to be used by the Contractor in performance of warranty work. Any spare part from SEPTA's stock that is used for warranty by the Contractor shall be replaced by the Contractor with a new part of original quality, to the latest configuration, and with a new original warranty.

The Contractor and all of his subcontractors and suppliers must also maintain in stock in their warehouses sufficient levels of consumable and routine maintenance spare parts to allow SEPTA to purchase them and have timely delivery to support its preventive maintenance activities. SEPTA shall maintain a sufficient level of preventive maintenance parts based upon replacement schedules contained within the publications, and a level of consumable parts based upon Pilot Locomotive experience and Contractor recommendations.

1.13 SUPPORT EQUIPMENT AND SPECIAL TOOLING

1.13.1 Support Equipment

The Contractor shall examine the existing support equipment inventory at the maintenance and repair facilities of SEPTA and shall submit to the Engineer by the delivery of the Pilot Locomotive a list of common support equipment recommended to be purchased, to effectively maintain and repair the locomotives. Support equipment is defined as the usual hand tools, generic test equipment, jacks, hoists, cranes, etc., that are required in order to maintain, operate and overhaul the locomotives and
their components and which are considered common shop equipment used in the United States, available as standard catalog items from at least two domestic U.S. suppliers.

1.13.2 Special Tools
The Contractor shall supply four complete sets of all specialized tooling, jigs, fixtures, measurement devices and so forth which are necessary for the inspection, testing, maintenance, removal, replacement, repair, disassembly, assembly, lubrication or overhaul of any equipment on the locomotive, that are not commonly available from commercial tool suppliers as standard catalog items. The Contractor shall assume that SEPTA will be responsible for the purchase of any tooling or equipment which is available as a standard (non-specialized) commercial grade catalog item from at least two domestic U.S. suppliers. Any items beyond this shall be the responsibility of the Contractor. Items shall be of heavy-duty commercial grade quality. These shall include those tools and devices not normally found in a mechanic’s or electrician’s standard tool kit. Examples include fixtures needed for disassembly and repair of the trucks, including drive assemblies and wheels, wire connector assembly or disassembly tools, hydraulic pullers for motor shaft couplings, clearance gauges, special lifting fixtures, special assembly benches or fixtures, wrench adapters, bearing pullers, guide sleeves, etc. Emphasis shall be placed on specialized tooling for the overhaul of electrical, mechanical, pneumatic and electromechanical equipment. Complete manuals explaining the use of the gauge or tool and its care and maintenance shall be included. Drawings for all fabricated special tools shall be included in the drawings database showing all dimensions and materials, and part lists shall also be supplied. The Contractor shall provide part numbers and prices for all special tools and maintenance equipment to enable SEPTA to purchase additional quantities. The Contractor shall submit a listing and description of all special tooling to the Engineer for approval. All items shall be delivered by the delivery of the last production locomotive.

1.13.3 Spare Parts
The Contractor shall provide Spare Parts for all apparatus and components of the locomotives in the quantities and configuration listed in the Price Proposal. All assemblies shall be delivered as called for. All items shall be identical with corresponding items as supplied on the locomotives and any changes to parts made on the locomotives before or during the warranty period shall be made by the Contractor on applicable Spare Parts at no cost to SEPTA. Where appropriate all parts shall be packaged for long-term and/or protected storage.

The contractor shall also provide an electronically controlled recording medium such as a database or spreadsheet where all parts and materials are listed by name, contractor part number, supplier part number, and quantities. A full record of deliveries and extractions from stock shall also be recorded within the medium as parts and materials are delivered or used.

As part of its base cost, the Contractor shall supply a quantity of consumable-type spare parts, other than lubricants, required to support operation of the base quantity of locomotives for a period of 6 months from delivery of each locomotive. These parts shall be based upon the consumable parts identified in the maintenance manuals, such as HVAC filters, compressed air system filters, brake shoes and pads, windshield wiper blades, interior lamps and exterior bulbs including indicator LED’s, pantograph carbons, and the like required to support all daily, periodic, preventative and any other type
of scheduled maintenance. Also to be included are two operator seats, and two locomotive sets of side windows, including handles and elastomers. Other parts to be included are two locomotive sets each of the following items: all pneumatic hoses, coupler electrical cables and tappet valves, overhead heater protective thermal fuse elements. The consumable parts list shall be provided during the Detailed Design Review with the consumable spare parts delivered prior to the delivery of the Pilot Locomotive.

1.14 TECHNICAL SERVICES

The Contractor shall provide at the SEPTA Frazer Shop, or other location on the SEPTA Railroad Division so designated by the Engineer, the full-time services of one competent Contractor Field Site Manager who is proficient in the English language, fully qualified in the maintenance and operation of the locomotives and capable of directing a field service staff. The Contractor Field Site Manager along with Contractor Field Service personnel shall assist SEPTA in overcoming any difficulties in the operation or maintenance of the locomotives and shall assist and explain troubleshooting techniques to SEPTA personnel.

The Contractor Field Site Manager shall have full authority to approve any component failure claims, the need for locomotive modification, supervision of the modification process or warranty claims. Status review meetings shall be held every 7 days with the Engineer or designated personnel, and shall include representatives of any subcontractor or supplier whose equipment is either receiving field modification, has problems identified requiring modification to correct, or which has performance problems which will require engineering effort to correct. Failure analysis of every defective component, unless otherwise approved by the Engineer, shall be performed by the Contractor within 30 days. A written agenda shall be received by the Engineer at least 24 hours prior to each status review meeting.

The Contractor Field Site Manager shall be available from the delivery of the Pilot Locomotive to the end of the basic warranty period, as extended. Suppliers shall provide assistance to the Contractor as required to assist in support of their equipment's operation through the warranty period. The Contractor shall supply an office trailer for its staff's use, and shall be responsible for its transport, electricity and telephone service. A separate telephone line with recording device shall be included to allow 24 hour receipt of messages from the Engineer.

To handle technical and warranty issues which are beyond the ability of the Contractor Field Service personnel, the Contractor at no cost to SEPTA shall continuously make available to SEPTA, no more than 48 hours after notice from the Engineer, the services of qualified subcontractor Service personnel during the term of this Contract and the warranty period as extended, for the purpose of handling such service or warranty problems. The Contractor shall also make available at no cost to SEPTA such additional specialized technical assistance as may be required from time to time during this period. This assistance shall continue until the issue in question is resolved to the satisfaction of the Engineer.

1.15 LOGISTICAL SUPPORT

A description of a Contractor-administered plan to implement warranties and provide technical assistance and repair parts during the lifetime of the locomotives must be submitted and approved by the Engineer prior to shipment of the Pilot Locomotive. As part of the plan, the Contractor must provide
a complete listing of every supplier used to provide parts on the locomotive, location of supplier parts depot(s), identification of supplier personnel SEPTA should contact to purchase spare parts or to obtain price information for all Contractor and supplier components and their related parts, and the methodology the Contractor and his suppliers will use to process and track customer orders.

The plan must also detail how the Contractor intends to implement the warranty program. This shall include the administrative control of the flow of warranty-related defective parts from SEPTA to the Contractor and repair parts return to SEPTA, the availability of those parts and components which the Contractor and his suppliers will need to support warranty without dependence on SEPTA purchased spare parts, the method of control for submittal, review and approval of SEPTA warranty claims, and payment of claims to SEPTA.

The Contractor shall furnish to the Engineer prior to delivery of the Pilot Locomotive a list of the type and quantity of standard replacement parts and incidental hardware which SEPTA should keep in current stock, based on the Contractor's knowledge of the locomotive design and ordering lead times. The list shall be submitted a second time with updated information prior to the delivery of the first production locomotives. This listing shall be in a format acceptable to the Engineer.

The Contractor's Field Site Manager shall be given full authority to act on behalf of the Contractor and his suppliers to approve SEPTA's warranty claims as necessary for payment to SEPTA. Action on claims submitted by SEPTA's field representative to the Contractor's Field Service personnel must be taken within 7 days of claim submittal. In the case of disputed claims, the Engineer and the Contractor shall review, negotiate and resolve such claims on a monthly basis. Invoices for approved claims will be submitted by SEPTA on a monthly basis. Payment shall be made to SEPTA within 30 days of the receipt of the invoice by the Contractor.

1.16 AS-BUILT DRAWINGS

1.16.1 Drawings

Unless the Contractor has proposed an “as-built” make and model locomotive meeting the requirements as defined in Section 1.2.3, and gained SEPTA’s concurrence as described in Section 1.3.4, the following requirements shall apply:

Within one year following the delivery of the final locomotive, the Contractor shall supply the Engineer with complete and approved sets of every as-built drawing used in the manufacturing and construction of the locomotives, and for all other items of material and/or equipment supplied. Two complete sets of the drawings shall be supplied on computer CD-ROM (including any special font files), and two complete sets of the drawings shall be supplied as hard copy drawings plotted on vellum. All electronic versions of drawings shall be prepared using AutoCAD 2002 software, or more current version as approved by the Engineer. Each electronic drawing must be capable of being opened and have editing capabilities using the software selected. The drawings shall be completely updated via the Contractor’s Configuration Management system (see Section 1.10) until the end of the warranty, including any extensions. See Section 1.21 for additional information on software and file format requirements.
Each AutoCAD drawing should look exactly as intended when opened with a standard AutoCAD 2002 program. They shall not require any special text fonts. Whenever possible, the drawing creator shall not use any exotic or special fonts in place of standard, easily translatable text styles. If any special fonts are used, the font files must be supplied on each CD-ROM. The quantity of drawing "layers" shall be kept to a reasonable minimum. Each drawing shall be drawn to full 1 to 1 scale whenever possible. Dimensions should always be at the proper scale after "exploding" Block entities.

Each drawing shall have a maximum size of 3 feet 8 inches wide and 2 feet 10 inches high. A limited number of drawings in larger roll sizes for electrical or pneumatic schematics may be supplied if approved by the Engineer. Every drawing shall have a SEPTA title block containing the notation "SEPTA High Speed Electric Locomotive", the drawing title (including system or subsystem identification), drawing number, Contractor's name, revision number and dates of all revisions, listing the changes made in each revision. A bill of materials shall also be provided for each drawing number, which shall contain the part number identification for each individual part, the drawing number for individual parts where drawings have been assigned, the drawing number showing the next higher assembly, and the weight for each part. All drawing formats shall be approved by the Engineer.

The drawing sets submitted to the Engineer shall contain a copy of every drawing used by the Contractor, every subcontractor and every supplier in this procurement except as otherwise agreed to by the Engineer. This shall include all "off the locomotive" material and/or equipment supplied under this Contract, all diagnostic tools and all special tools. The drawing sets shall be organized in a logical, drawing tree system, based on the physical configuration of the locomotives. This shall include both fully dimensioned manufacturing part drawings as well as dimensioned assembly drawings for all parts, subassemblies, assemblies and arrangements.

Circuit board level detail, installation and connection drawings shall be included. Also included shall be general arrangement drawings, color schedules and clearance drawings. Drawings shall be prepared in accordance with ANSI Y14 drawing standards using third angle projections. First angle projection shall be allowed provided all views are labeled, including the front, top, bottom and side views. Electrical schematic drawings shall indicate all wire numbers, references to other drawings of any and all manufacturers to which connections are made, nominal voltages, currents and frequencies, significant resistance values, and the rating of all loads. Devices shall be labeled in agreement with the identification appearing on the actual device, and their locations on the locomotives shall be shown. Pneumatic schematic drawings shall be prepared in a similar fashion.

If there are any drawings which the Engineer agrees cannot be supplied in electronic format, the Contractor shall supply two complete sets of these drawings on clear approved static-free polyester drafting film 0.003 inch thick with a matte finish on both sides. Plastic lead or black ink shall be used. Two complete sets of these drawings shall also be supplied on 35 mm microfilm aperture cards meeting Military Specification MIL-9869B. The microfilm itself shall conform to Military Specification MIL-M-9868B for type 1 silver halide microfilm, class I, for first generation usage. Each aperture card shall have printed on the top "Silverliner V", the drawing title, supplier name (if not a Contractor drawing), drawing number, revision level and date of last revision.
1.16.2 Database

A drawing and bill of material (BOM) database shall be created that will contain all associated drawings and materials used by the Contractor and Suppliers of equipment for the locomotives. All drawings associated to the configuration and assembly of the vehicles must be included. Minimum fields associated to the drawings shall contain the following subjects:

- Contractor's drawing number
- Electronic file name
- Supplier's drawing number (as applicable)
- SEPTA drawing number (if applicable)
- Drawing size
- Number of sheet and total number of sheets (i.e. 2 of 4)
- Revision level (in letters, starting with "A")
- Official title (without punctuation or abbreviations)
- Description in layman's terms using keywords to aid in searching
- Drawing number of the next level of assemblies
- Contractor/Supplier name
- System, subsystem, major component (as applicable)

The BOM lists shall be complete and capable of creating, displaying and printing indented parts lists from the component or system level chosen. Minimum fields associated to the BOM shall contain the following subjects:

- Part number
- Drawing number for each listed part
- Contractor/Supplier name
- System, subsystem, major component (as applicable)
- Unit of measure
- Description
- Quantities and item number in relation to the associated drawings (and/or sheet numbers) where they are used.

Reports and queries shall be developed and designed to find, cross-reference and sort the information by drawing number, drawing description, BOM part number, individual part drawing number, system or
major component, Contractor or Supplier. If the drawing was made obsolete during the length of the Contract, it shall be so listed and identified, along with the identity of any superseding drawing number. One extra additional field of 11 characters shall be included to accommodate the SEPTA class and lot numbers for future use. A form shall be designed to input the SEPTA class and lot numbers into the associated field. The design of the reports, queries and form shall be submitted to the Engineer for approval.

## 1.17 DELIVERY AND ACCEPTANCE

### 1.17.1 Authorized Shipment Inspections

The Contractor shall submit to the Engineer or his designee, an Authorized Exception Sheet a minimum of three working days prior to pre-shipment inspection for review. Line items on the sheet shall consist of items not performed at the Contractor's facility due to lack of materials, open ECP documents effective at the time of shipment for the locomotive ready for pre-shipment inspection, or any other item within the work scope of the Contractor's facility which the Contractor feels does not affect the vehicles safe and complete operation or passenger comfort thus hindering shipment. Included with each item there shall be a full description of the why the work cannot be completed prior to shipment, what work is to be included and a schedule of when the work will be performed.

Shipping exceptions will not be viewed as an alternate avenue for the Contractor to ship. SEPTA reserves the right to enforce all work to be performed at the Contractor’s facility to be performed there prior to shipment and decline any request for authorization of any exception or require the exception(s) to be completed prior to either performing the pre-shipment inspection or final acceptance of the locomotive.

### 1.17.2 Release for Shipment

When the Pre-shipment Inspection specified in Section 1.17.1 has been concluded to the satisfaction of the Engineer’s Representative, and any defects discovered are fully corrected, the Contractor shall present a Release For Shipment Authorization document to the local SEPTA Representative for the purpose of obtaining SEPTA’s authorization to ship. No shipment of locomotives or other completed material shall be made by the Contractor to SEPTA without such a document. Shipment of locomotives without a SEPTA authorized release for shipment document may result in the refusal of delivery on SEPTA property.

Neither a Pre-shipment Inspection nor a Release For Shipment will be considered by the Contractor to constitute acceptance of a locomotive or other material. The Contractor shall prepare each locomotive for shipment in such a way as to allow it to be placed in service immediately upon arrival following removal of any necessary shipping devices and installation of any removed parts. Any parts removed for shipment or other necessary special equipment needed for shipment shall accompany each locomotive.

All locomotives or other material shall be properly packaged or otherwise prepared for any shipment made during any phase of assembly. If shipment is by sea, all material including the locomotive body shall be shipped below deck. If this is not possible, locomotive body shipment on deck may be made, if
approved by the Engineer, only if special arrangements are made to insure that no damage or exposure to the marine environment will take place under worse possible storm conditions.

### 1.17.3 Acceptance Testing and Inspections

As items of material or equipment other than the locomotives are received, the Engineer will have performed such acceptance inspections and tests as are deemed necessary to determine if each item is in conformance with the Technical Specification, both as to configuration and performance parameters. Certain of these procedures may be performed on a sampling basis, and others may be performed only on material or equipment which give indication of marginally acceptance performance, reliability or quality. Representatives of the Contractor may witness acceptance tests and inspections. Any damage or defect discovered during the acceptance inspections shall be corrected immediately by the Contractor.

As the locomotives are received, the Engineer will oversee acceptance tests on each locomotive, as provided for in Section 16. These tests, including performance testing, shall be performed by the Contractor or under its direction and at its expense except for the SEPTA provided items listed below. The Contractor shall provide all personnel and instrumentation necessary to monitor and record test results. SEPTA shall provide all track facilities, catenary power and operating personnel at its expense for these tests. All tests shall be conducted in the presence of the Engineer, and at times agreeable to SEPTA and the Engineer. Any damage or defective condition discovered during the acceptance testing shall be corrected immediately by the Contractor. No locomotive shall be accepted if it contains any defects or if not in a complete ready-to-run in revenue service condition. At the option of the Engineer, a locomotive which was acceptance tested and had defects which were later corrected by the Contractor may be required to be retested, repeating some or all of the original procedure, if the Engineer has reason to believe that the original defects were of a serious nature, or if there is some questions as to the nature of the repairs.

### 1.17.4 Notification of Acceptance

When acceptance inspections for items of material or equipment other than the complete locomotive have been completed, the Engineer will provide the Contractor within 10 days either a Certificate Of Acceptance document or a rejection notice. Any and all deficiencies discovered during Acceptance Inspection or subsequently shall be corrected as provided in the Contract Documents. When each locomotive has properly completed all acceptance testing and contains no known defects, the Engineer will promptly issue a Certificate Of Acceptance document to the Contractor.

### 1.17.5 Defects

If any item of material or equipment is delivered incomplete, does not meet applicable federal safety and emission standards, contains any defective or damaged parts, or fails in any other way to meet the Technical Specification, the Contractor shall arrange that the item be completed or deficiencies corrected, or damaged parts removed and new or repaired parts consistent with the requirements of a new item installed, without any cost whatsoever to SEPTA.
1.18 LOCOMOTIVE HISTORY BOOK

The Contractor shall provide the Engineer an “As-Built” “Locomotive History Book" within 30 days following that locomotive’s acceptance.

The Locomotive History Book shall contain two types of volume information, first being a history of the physical locomotive and the second being individual truck history books for each truck. The full Locomotive History Book will thus consist of 3 volumes to cover the locomotive and trucks as delivered to SEPTA as a single unit.

Each book shall contain the following as a minimum, as applicable for the volume type:

a) Locomotive number and Contractor's construction number, if used.

b) Certified locomotive weight records. (full locomotive weight with trucks)

c) Serial numbers and configuration of all major units and major individual assemblies installed on the locomotive. The items listed shall be approved by the Engineer. Item part numbers and description shall be included.

d) A listing of all as-built drawings by revision level to define the level of assembly of the locomotive as built in the production assembly process.

e) A listing of all modifications either pending or completed that apply to the locomotive, containing the following in numerical order:

   - Each Engineering Change Notice

   - Each Field Modification Instruction, with a cross reference to the Engineering Change Notice.

   - Concise description of modification or change.

   - Date of completion.

a) A summary of each inspection performed on the locomotive or any part thereof, including disposition and Engineer approval. (Refer to the Quality Assurance provisions and the production conformance test requirements for details).

b) All original data sheets from the production conformance and vehicle acceptance tests.

c) Wheel, journal bearing and gear unit axle mounting records and material certifications.

d) All documents related to locomotive shipment.

e) Provision for inspection, servicing and maintenance records during the warranty period (including space for dates, description, and comments).

Documentation shall be distilled into Adobe Acrobat PDF electronic file format. A single file shall be created as a Locomotive History File for each locomotive starting with a title page containing the notation "Locomotive History Book" and the locomotive number. Each locomotive history shall be
updated by the Contractor every 45 days until the conclusion of the warranty period. The serial number and configuration list shall include the date installed and shall allow for future revisions arising from retrofits and from maintenance actions. A concise Table of Contents listing all subjects of data to the lowest levels shall be developed and used as the main bookmark for the file. Locomotive history data that is available in electronic form shall be distilled from the authoring (originating software file) document. Other data forms that have been used for shop use or test sign-off that contain actual signatures that cannot be distilled from authoring documents may be scanned into PDF format. All scanned images shall be properly aligned and not skewed. Each record distilled shall be inserted into the main Locomotive History file for that locomotive in the order of the Table of Contents to allow sequential printing of the locomotive history book if necessary. The appropriate bookmark for the subject shall be linked to the corresponding page. To keep the size of the file reduced, distillation shall be performed at an appropriate setting to accommodate clear, distinctive images from both screen and average desk top printing. During the actual distillation of files into the PDF format a DPI setting of 300 for distillation process is recommended.

If the file size becomes unmanageable, alternate methods may be submitted for review, such as external links to separate section files for the locomotive history data. However, under no circumstances are external links to be used for single, individual page files containing data other than a master PDF file used to link separate section files together to create a full locomotive history book format. The lowest level file shall contain a section of the locomotive history at a minimum. An additional PDF file shall be created which lists all locomotive history files for the locomotives produced. External links shall be made to each locomotive’s main Locomotive History File making this file an overview of the locomotive history files for the fleet. A complete plan of the architecture, TOCs, and file formats shall be submitted to the Engineer or his designee for approval. Each locomotive history shall be submitted to SEPTA in CDR format, individual to each locomotive’s history.

1.19 ENGINEER’S INSPECTION TEAM

The Contractor’s Quality Assurance operations shall be subject to Engineer verification at any time. Verification will include surveillance of the operations to determine that practices, methods, and procedures of the program are being properly applied; inspection to measure quality of items to be offered for acceptance; and inspection of items awaiting release for shipment to ensure compliance with all requirements of the Contract Documents.

1.19.1 Field Office Requirements

The Contractor shall provide the Engineer and his Field Representatives private office space for a SEPTA Field Office on the Contractor’s facility, at the cost of the Contractor. If work is performed extensively at more than one facility either on the Contractor’s property or Subcontractor’s location, additional offices shall be provided as needed. Space requirements shall be determined for subcontractor satellite offices on a case by case basis.

The offices shall be private and located within a reasonable distance from the work being performed, preferably within or directly adjacent to the final assembly building. The office shall be modern, clean, painted, efficiently lighted, heated and air conditioned. Office cleaning shall be maintained by the
Contractor. When one to four SEPTA Representatives are present, the office space shall be sufficient to accommodate a minimum of four personnel, including desks, file cabinets and associated office furniture. Desks and file cabinets shall be lockable and all keys submitted to SEPTA. Amenities for bottled water, microwave and small refrigerator will also be included within the office for support of the Representatives. All office equipment shall be functional, be in good condition and are subject to SEPTA review and acceptance. In the event the number of the SEPTA inspection team are increased to accommodate the Contractor’s work schedule, office space, furniture, telephone and computer equipment shall be expanded to meet the needs of the additional staff level. Also within the office, there shall be a conference table capable of seating a minimum of 8 individuals for conferences during visits by the Engineer and daily activities. The field office shall be securable with keys distributed to SEPTA Field Representatives and the facility security and maintenance personnel as applicable.

Telephone lines shall be provided for each desk within the site office to supply voice communications in addition to a dedicated fax line. Speaker conferencing capability shall be provided at the conference table. Communications equipment including telephones, answering machine and a fax machine shall be provided for by the Contractor. Long distance & international telephone service shall be provided by and at the cost of the Contractor. If video conferencing is used for meetings, the Contractor will be responsible for all audio visual additions as necessary to conduct meetings from the Field Office’s conference table.

A photocopy machine capable of high quality copies shall be provided either within the Field office or nearby (adjacent) area.

### 1.19.2 Computers

The Contractor shall supply computers in field offices for use of the SEPTA Representatives. A computer shall be provided at each representative’s desk, as determined by staff requirements to cover local activities. One computer shall be provided on satellite offices where 2 or less are assigned, however if 3 or more full time representatives are needed, the requirements for the Contractor’s based field office shall be followed. While in use in SEPTA offices, the computers shall be considered to be under SEPTA control and not networked to the Contractor’s facility.

The computers shall be desktop style built by a Gartner Group Tier 1 manufacturer, with the latest PC processor technology and architecture. Eight gigabytes of RAM size shall be supplied within the units minimum, or more if needed to accommodate multi-tasking of multiple major software programs without reduction of speed or interruption of the operating system. Hard drive space size shall be sized to accommodate all program software used during the execution of the contract in addition to large format data storage capabilities while offering sufficient space to allow smooth operation. High speed DVD-RW with CD-RW capability drive (or drives) shall be included in addition to any other high capacity removable drive formats used by the Contractor for information exchange. Monitors shall be flat screen 22 inch diagonal minimum. Each unit shall be USB 3.0 capable.

The office shall contain a network adaptable laser jet printer capable of printing multi paper sizes, with color printing and scanning capabilities. If such a unit is unavailable, additional peripheral items shall be provided per office as follows: one scanner (1200 DPI minimum); one desktop color printer capable of producing graphic photo images with the capacity of printing 11 inch by 17 inch format; one black and
white laser jet printer for general use. Hard-wired networking hubs and software shall be provided so that each computer station will have full use of the equipment.

General use software in addition to any virus protection programs shall be provided by the Contractor as necessary as covered in Section 1.21.1.

Maintenance, troubleshooting and technical support of the computers used at the Contractor's facility and any local computer systems used within the office shall be performed by the Contractor. Removable disk drive media blanks and printing supplies shall be provided by the Contractor as needed.

1.19.3 Internet Access

The Internet shall be heavily used as a communication tool during the duration of the Contract. The Contractor shall provide and maintain a high speed connection, T1 or better, to all major SEPTA Field Offices during the Contract. Access shall be independent of the Contractor's connection and/or internal networks.

1.19.4 Data Access

The Contractor and associated Subcontractors shall provide the Field Representatives with all information, tools and test equipment necessary to perform their tasks of controlling conformity of the material or equipment to the Technical Specification. Upon request, the Field Representatives shall have access to current prints, drawings, material lists, production control documents, QA/QC reports and audits or any other document involved in the activity of the development of the locomotive and or fleet production thereof. SEPTA Field Representatives reserve the right to request, receive and maintain copies of such documents as further covered in Section 1.19.4.

1.19.5 Function and Authority

It is the intent of this Contract that the inspection of components be the responsibility of the manufacturers and the Contractor. This inspection will be performed at the plant of the manufacturer giving him every opportunity to correct, under factory conditions, any inadequacies found. The function of the Engineer's Field Representatives is to provide engineering representation for the Engineer at the site of the Contractor and his subcontractors as required to interface with the Contractor's project management concerning daily operations, perform technical liaison functions, verify and approve the work as it progresses, witness production conformance and Quality Assurance tests, and conduct the Pre-shipment Inspection of the locomotives and components. The Field Representatives will include the Engineer and others designated in writing. The Field Representatives shall have complete access to any and all workshops at all times when work is being performed on this Contract, including subcontractor workshops where any major components, subassembly or assembly is being fabricated or assembled.

The use of Field Representatives by the Engineer does not in any way relieve the Contractor and his subcontractors from the requirements of the Quality Assurance Program. At all times the Contractor and his subcontractors bear the sole responsibility of inspection and testing of the locomotives during assembly, and the presence (or lack thereof) of Field Representatives does not lessen this responsibility.
The Field Representatives will not be used as substitutes for the Contractor's or any subcontractor's work force. When repetitious rejections must be made by the Field Representatives of either a manufacturer's or the Contractor's work to maintain proper quality, this condition will be cause for the Engineer to withdraw the Field Representatives, and to consider all work stopped until a satisfactory agreement is reached.

1.19.6 Field Representative Availability

Verifications, inspections or testing of the locomotives shall not be conducted by the Contractor for the Engineer after SEPTA’s normal business hours or on a Saturday, Sunday or Holiday, except for specific tests or inspections as approved by the Engineer by prior written agreement. Failure by the Contractor to comply with this provision shall be considered reason to reject such locomotive. Subsequent inspections shall be rescheduled at the convenience of the Engineer, any penalty clause notwithstanding.

The Contractor shall give the Engineer 14 days notice prior to any testing and or inspections under the following conditions:

- All Engineering tests, production tests, first article inspections at the locomotive component, systems and full locomotive levels during the Pilot Locomotive program.
- In the event there is no full time SEPTA Representative present at the Contractor's facility.

During the manufacturing sequence of the production locomotives, if a Field Representative is already present at the Contractor's facility, prior notice of inspections or testing must be given to the Field Representative at least 24 hours prior to the event, at which time the inspection shall be scheduled at SEPTA's convenience.

1.19.7 Verifications and Inspections During Manufacturing

It is the Engineer's intention to have one or more Field Representatives present at the site of the Contractor's shops continuously monitor and/or witness the manufacture or assembly of the items of material or equipment. The presence of SEPTA personnel for these purposes shall in no way reduce the Contractor’s responsibility for a properly staffed and effective Quality Assurance/Quality Control program.

In any event, a Field Representative present at the Contractor's work site for a sufficient portion of the time during performance of this Contract so as not to unnecessarily impede, interrupt or disrupt the manufacture and delivery of the material or equipment according to the Contractor's Delivery Schedule due to lack of coverage. Rework due to discrepancies found by Field Representatives during the manufacturing, testing and/or final inspection periods shall not be considered as an interruption to manufacturing and the Contractor shall absorb any schedule loss due to such action.

SEPTA Field Representatives reserve the right to identify “hold points” and make prior arrangements to verify completed work at specific stages of construction. These hold point may be based on established Contractor QC in process inspection points or other stages of manufacture as deemed fit by SEPTA.
During the assembly phase, each event shall be considered to be a verification of compliance to the approved design, materials and workmanship of the locomotive and gage the effectiveness of the Contractor's Quality Assurance/Control activities. Prior notice of intent will be given to the Contractor identifying which area has been chosen for verification. Requirements for such a verification will be totally completed work for the area(s) identified within the notice of intent. Inspection of the area must be complete and the results must be presented at the time of the verification and the area(s) offered for verification during normal (SEPTA) working hours. Lack of response to a verification request will lead to the area in question being exposed by the Contractor prior to SEPTA performing a pre-shipment inspection thus effecting the locomotive's shipping authorization. The Contractor will bear the expense for such action since the request was submitted prior to the area's enclosure.

When a Field Representative is on the Contractor's facility and in the event pre-delivery testing, production verification and or a pre-shipment inspection conflict upon the Field Representative as being offered simultaneously, the Contractor shall choose the priority of either pre-delivery testing or pre-shipment inspection. The verification request shall take least precedence. The Field Representative shall start and complete the function determined as the priority prior to performing the next function.

Prior to SEPTA performing a verification, test or inspection, the locomotive(s) shall be properly lighted and or powered to accommodate the function as needed. Access to the underframe shall be provided by a clean, dry and well lighted pit when deemed necessary for verifications and is a prerequisite during the underframe portion of a pre-delivery inspection. Inspection data and status updates shall be performed by the Contractor.

### 1.19.8 Pre-Delivery Testing

All pre-delivery testing shall be pre-tested and documented on authorized test forms prior to the test being offered to the Field Representative for official testing, thus creating a time for final adjustment and showing reliability during the official test. The pre-delivery testing shall not be in piecemeal, and once started it shall be continued to completion. In the event a Field Representative is not on site to witness such testing, the testing shall still be performed (pre-testing is still required), however a waiver shall be issued from the Engineer or his designee for a Contractor's QC representative to take his place as the witness to the test. Test data and status updates shall be performed by the Contractor.

### 1.19.9 Pre-Shipment Inspections

The Engineer will assign a Field Representative to perform a Pre-shipment Inspection upon the completion of each locomotive using a printed inspection form. The Contractor shall arrange the schedule for shipment of each locomotive to provide a minimum of 2 days for inspection of the locomotive after it is fully completed and has had a comprehensive final inspection performed by the Contractor’s Quality Control. All pre-shipment tests must have been completed and accepted. All Contractor QC inspection discrepancies must be reworked and complete, the locomotive cleaned, judged ready for shipment and free of all workers.

Prior to the pre-shipment inspection the Contractor shall present the following items:
Section 1.20 DEFECTIVE WORK

Should the Engineer have reasonable evidence that defective work or material has been permitted by the Contractor or a subcontractor, in an area which was not covered by a verification notice as mentioned above, the Contractor or subcontractor shall furnish the appliances and labor for making such investigation and inspection as may be required by the Engineer in writing. Any imperfect construction or materials which may be disclosed shall be corrected promptly. During any period of time from construction to acceptance, any inadequacy of design, construction or testing or any damage by any cause whatsoever, except that caused directly by SEPTA, shall be corrected by the Contractor at no cost to SEPTA. If the investigation discloses no defects, the expense of such investigation will be borne by SEPTA, and the delay caused by such investigation will be considered as being beyond the Contractor’s control.

Section 1.21 ELECTRONIC INFORMATION CONTROL

The Contractor shall compile, store and transfer documents via electronic binary files whenever possible. Official correspondence and/or technical submittals required in printed form by this specification shall be accompanied by the electronic copy of each document in a software format agreed to by the Engineer. Acrobat PDF formatted files shall be used as the standard electronic format medium for submittals and correspondence. Upon SEPTA’s request, the Contractor shall supply the originating authoring file to assist in reviews and data assessment on a case by case basis.
**1.21.1 General Use Software**

All general use software shall be designed to run on Microsoft Windows platform based PCs. The following software shall be used as a guideline:

<table>
<thead>
<tr>
<th>Software Type</th>
<th>Software</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project Management Correspondence</td>
<td>Microsoft Word</td>
</tr>
<tr>
<td>Databases, Spreadsheets &amp; Presentations</td>
<td>Microsoft Office</td>
</tr>
<tr>
<td>Drawings, Schematics</td>
<td>AutoCAD 2002 compatible</td>
</tr>
<tr>
<td>PDF file creation and viewing</td>
<td>Adobe Acrobat</td>
</tr>
<tr>
<td>Graphics, Digital Pictures</td>
<td>Adobe Photoshop</td>
</tr>
<tr>
<td>Project Scheduling</td>
<td>Primavera, or software meeting the requirements of 20.7.1, as approved by the Engineer</td>
</tr>
</tbody>
</table>

The Contractor may request to use of alternate programs in lieu of those listed for Engineer approval. However, if approved, the Contractor shall bear the cost of new software and the cost of training SEPTA project and support personnel, both in Philadelphia offices and in the field, on the use of the software.

**1.21.2 PDF Files**

Adobe Acrobat PDF files shall be used as the standard electronic ("softcopy") format for written communications, presentation submittals, drawings, schematics, manual publications and training documents. PDFs shall be distilled from the authoring binary files from software as referenced in 2.19.1 which were used to create them. The originating authoring binary files shall also be considered as deliverables as applicable for their type and subject as required in the Technical Specification.

Distillation of the authoring files shall be performed using standard dpi distillation, using the Acrobat 7.0 or higher setting. All distillations shall result in PDF documents that have the ability to be indexed and searched for text. When distilling, the proper paper size for the subject shall be used as a distillation setting. This is particularly important for distilling drawings. Drawings should be distilled based on the plotter setting for the drawing to maintain details. Printing of large format drawings shall either be performed by plotter or reduced in size to 11X17 (tabloid) using the print-to-fit-function in Adobe Acrobat Reader.

In cases where single file PDF submissions originate from multiple files, the files shall be imported into the parent PDF by using the “Merge into a single PDF” command resulting in all pages being shown within the file and all information being available for searches by the user and the capability of being included in Adobe index file development. Internal attachment of files within the PDF shall be limited to binary files if required or requested (such as spreadsheets where data can be indexed or sorted during reviews).

Any PDF covering large amounts of information shall contain internal bookmarks to aid in navigation to particular subsections. Publications for manuals and training shall be fully bookmarked for use on the SEPTA Vehicle Technical Information Library (VTIL) system as referenced in Section 1.21.3, below. For
this purpose, it is urgently recommended that Adobe Acrobat software be used for distillation and installed on computers using software as required in Section 1.21.1. This will allow a macro to be installed where if headers and styles are used in the binary files, settings and adjustments can be made to automatically produce a full hierarchy of bookmarks during the distillation process. If not, the Contractor will be responsible for creating the bookmarks manually.

Creation of PDF files from scanned images only, will be restricted to those allowed by the Engineer or as required by the Technical Specification. PDF files of scanned information may not be used for formal publications or training. The Contractor is responsible for all information for these documents to be distilled from parent, editable documents using software as required in Section 1.21.1.

Scanned documents shall be limited to archival documents which contain handwritten initials and/or stamps denoting signed-offs for steps within the manufacturing, testing or inspection of individual locomotives or components. Any document that contains recognizable text in its image shall be run through Adobe Acrobat’s OCR recognition to capture what might be available as text. When documents are scanned, careful attention will be taken to not allow misalignment of the pages.

Documents agreed to be compiled primarily of scanned images such as Locomotive History Books shall have bookmarks created in the form of a detailed Table of Contents down to the lowest document level. The TOC bookmarks shall be linked to the documents to allow particular records to be identifiable and accessible by clicking on the bookmark to view the subject matter.

Scanned “no text” information in the form of document attachments may be allowed to be imported into an existing PDF file that is searchable and capable of indexing if the information is supplemental to context to the file and not the primary means of communicating the subject’s information.

The Engineer and Contractor shall appoint a designee to coordinate efficient use and control of the PDF files for items such as file naming conventions, security levels, bookmarks, revision level controls, other individual file format requirements and the use of digital signatures. All details associated to PDF files and use shall be approved by the Engineer.

1.21.3 VTIL Related PDF Files

VTIL related publications shall be developed using a numeric numbering system that reflects the internal organization of each chapter’s hierarchy by chapter, section and subsections as applicable per subject. Each chapter of a manual set shall be an individual file covering the subject of the chapter and act as a stand-alone file. Each file shall contain a full set of “internal” bookmarks for each section and subsection contained within the file. Bookmarks shall be shown in the navigation plane in the level of its “parent/child” hierarchy.

“External” bookmarks, otherwise known as bookmarks that call up an external file shall be also added to each chapter’s navigation pane. These external bookmarks contain bookmarks that will enable the user to change chapters within a manual set from the existing navigation pane. Example: if it’s a coupler – draft section within a Running Maintenance Manual set and the user wishes to go to the RMM truck section, clicking upon the external link will automatically open the truck chapter file.
All external bookmark link paths shall be “relative paths” based on the associated chapter files for that style of manual being within the same directory as the open file. Any other bookmarks that navigate to VTIL main pages shall also be based on relative paths that navigate the VTIL directory structure.

Selected documents shall be chosen for distribution via Adobe Acrobat PDF file formatting such as Locomotive History Books, test procedures for production related functional and acceptance testing, maintenance manuals, integrated parts lists and other technical documents related to the build, operation and maintenance of the locomotives.

Files required to be forwarded to SEPTA in PDF form shall be distilled using setting of Acrobat 7.0 or higher. All PDF files shall be distilled from the authoring documents created using authorized software as described in this section, resulting in PDF documents that can be automatically bookmarked, indexed and searched.

The PDF file produced from the distillation process shall match any published version of the authoring document. Where published documents will be produced after the creation of authoring files and PDF versions, formats will be carefully planned to accommodate both the electronic and published versions as outlined in Section 1.2.1. Page numbering will be matched to reflect the documents page numbers between the two versions. All files shall be editable by SEPTA for future document maintenance. All columnar data found within word processing files shall be presented in a table format. Graphics and illustration files shall be submitted in high resolution formats as described in Section 17.2.10. Any fonts used on the creation of authoring and/or PDF files shall be embedded and not restricted for use. PDF documents with definable chapters, sections and/or subsections shall be linked to their individual locations with bookmarks internal to the file in the fashion of a hierarchical format such as a Table of Contents.

All PDF files shall contain a bookmark structure consistent with the SEPTA Vehicle Technical Information Library (VTIL). It is the intention of SEPTA to coordinate these details with the Contractor as the various publications are developed. Each PDF file for a manual shall contain the information of a single section (chapter). A complete collection of all section files for a particular manual will represent a full manual by type.

Each manual PDF file shall contain Bookmarks for navigation within the manual. Two types of bookmark links shall be used, external (which opens another PDF section file) and internal (which goes to views within the file that is open at the time). All bookmarks must be placed in hierarchical form.

For externally linked bookmarks, level one bookmarks will consist of three external bookmarks. One shall link to the VTIL main page, the second to a VTIL search engine, and the third to the Silverliner V main page. Level two will be a bookmark with no link that identifies the manual that is now open. Level three shall consist of a list of all sections by number and title found within the manual, so when clicked the section file will automatically open. This will allow the user to click from chapter to chapter without having to return to a main page.

Bookmarks that are internal to the section’s individual file shall be included for all subsections found within the file (no other file’s subsections, only the one associated to the open file). All bookmarks shall be properly numbered and titled to the subsection they are linked to. The hierarchical structure of the internal subsection links are to be cascaded in the bookmark sections reflecting the hierarchy, and shall be inserted under the appropriate chapter link (this will be starting at level 4).
Information that covers a single subject and is not associated to larger information formats may be distilled into single PDF files. Where the file data represents a portion of a larger volume of information such as a manual or collection of test procedures, individual files shall be created at the section or chapter level (or individual test level), with internal bookmarks to the data contained within the file and external bookmarks that link the sectional document to a master PDF file containing a full TOC of the document being developed. External links shall be relative (vs. absolute) and shall be capable of being placed on SEPTA's local area network or run from a CD.

Opening options in the PDF file format shall be set to show bookmarks and page, with magnification at "Set Width" and "Continuous Page" settings. Distillation DPI settings shall be set to approximately 300 DPI to produce quality printing from a desktop printer without overly increasing the size of the file.

1.22 DELIVERY LOCATIONS

All material and equipment to be delivered by the Contractor to SEPTA shall be shipped prepaid at the Contractor's expense using a common or contract carrier of the Contractor's choice. SEPTA shall not be liable for the payment of any shipping, transportation, delivery, customs or unloading costs under this Contract.

All written or printed matter to be delivered to the Engineer, such as technical correspondence, submittals, publications, drawings, etc., and all computer equipment shall be delivered to:

SEPTA Rail Engineering  
New Vehicle Programs  
1234 Market Street  
Philadelphia, PA 19107-3780

All locomotives shall be shipped freight prepaid on their own wheels to SEPTA, Wayne Junction Electric Car Shop, Wayne Junction (Philadelphia), Pennsylvania. Wayne Junction is a railroad interchange point between SEPTA and CSX Transportation. Each locomotive shall be delivered must be fully assembled, tested, and ready to run following the removal of any special shipping equipment or requirements. The Contractor shall make all arrangements to use its own reporting marks for locomotive movement, and to have these reporting marks properly registered with the AAR UMLER reporting mark database. In addition, the Contractor shall equip both sides of each locomotive with a properly encoded AAR radio frequency transponder (electronic tag) unit mounted on the underside of the locomotive body for shipping, encoded with the Contractor's reporting marks, which the Contractor shall remove following delivery.

All spare parts, specialized tooling, diagnostic test equipment (other than computers) and other hardware, material and equipment shall be shipped freight prepaid to:

SEPTA Frazer Facility  
32 Sproul Rd  
Frazer, PA 19355
The Contractor shall be responsible for making all arrangements for delivery of all Contract material at its own expense. Every shipment of materials, spare parts, etc. shall have a fully itemized packing slip detailing all contents by quantity, name, part number, etc.

### 1.23 ABBREVIATIONS and ACRONYMS

The following abbreviations and acronyms used in this Specification shall have the meanings provided herein:

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Definition</th>
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<tbody>
<tr>
<td>AALA</td>
<td>American Association of Laboratory Accreditation</td>
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<tr>
<td>AAR</td>
<td>Association of American Railroads</td>
</tr>
<tr>
<td>AC</td>
<td>Alternating Current</td>
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<tr>
<td>ACSES</td>
<td>Advanced Civil Speed Enforcement System</td>
</tr>
<tr>
<td>ADA</td>
<td>Americans with Disabilities Act of 1990 (and regulations promulgated there under, including 49 CFR Parts 27, 37 and 38)</td>
</tr>
<tr>
<td>ADU</td>
<td>Aspect Display Unit, Cab Signals</td>
</tr>
<tr>
<td>AISI</td>
<td>American Iron and Steel Institute</td>
</tr>
<tr>
<td>ALCOA</td>
<td>Aluminum Corporation of America</td>
</tr>
<tr>
<td>ANSI</td>
<td>American National Standards Institute</td>
</tr>
<tr>
<td>AREMA</td>
<td>American Railway Engineering Maintenance Association</td>
</tr>
<tr>
<td>ARI</td>
<td>American Refrigeration Institute</td>
</tr>
<tr>
<td>ASA</td>
<td>American Standards Association</td>
</tr>
<tr>
<td>ASC</td>
<td>Automatic Speed Control System</td>
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<tr>
<td>ASHRAE</td>
<td>American Society of Heating, Refrigeration and Air Conditioning Engineers</td>
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<tr>
<td>ASME</td>
<td>Society of Mechanical Engineers</td>
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<tr>
<td>ASSE</td>
<td>American Society of Sanitary Engineers</td>
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<tr>
<td>ASTM</td>
<td>American Society for Testing and Materials</td>
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<tr>
<td>ASQC</td>
<td>American Society for Quality Control</td>
</tr>
<tr>
<td>ATC</td>
<td>American Society for Quality Control</td>
</tr>
<tr>
<td>ATCS</td>
<td>Advanced Train Control System</td>
</tr>
<tr>
<td>ATS</td>
<td>Automatic Train Control</td>
</tr>
<tr>
<td>AWG</td>
<td>American Wire Gauge</td>
</tr>
<tr>
<td>AWS</td>
<td>American Welding Society</td>
</tr>
<tr>
<td>BCP</td>
<td>Brake Cylinder Pressure</td>
</tr>
<tr>
<td>BTU/Hr</td>
<td>British Thermal Units per Hour</td>
</tr>
<tr>
<td>CAD</td>
<td>Computer Aided Drafting</td>
</tr>
<tr>
<td>CDRL</td>
<td>Contract Deliverable</td>
</tr>
<tr>
<td>CFC</td>
<td>Chlorinated Fluorocarbons</td>
</tr>
<tr>
<td>CFM</td>
<td>Cubic Feet per Minute</td>
</tr>
<tr>
<td>CFR</td>
<td>Code of Federal Regulations</td>
</tr>
<tr>
<td>CPMS</td>
<td>Catenary/Pantograph Measuring System</td>
</tr>
<tr>
<td>CPU</td>
<td>Central Processing Unit</td>
</tr>
<tr>
<td>CSA</td>
<td>Canadian Standards Association</td>
</tr>
<tr>
<td>CT</td>
<td>Current Transformer</td>
</tr>
<tr>
<td>CTCSS</td>
<td>Continuous Tone-Controlled Squelch System</td>
</tr>
<tr>
<td>Abbreviation</td>
<td>Description</td>
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<tr>
<td>dB</td>
<td>Decibel</td>
</tr>
<tr>
<td>dBA</td>
<td>Decibel, &quot;A&quot;-Weighted Scale</td>
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<tr>
<td>DC</td>
<td>Direct Current</td>
</tr>
<tr>
<td>DHT</td>
<td>Duct Heat Thermostat</td>
</tr>
<tr>
<td>DOS</td>
<td>Disc Operating System</td>
</tr>
<tr>
<td>DOT</td>
<td>United States Department of Transportation</td>
</tr>
<tr>
<td>EEPROM</td>
<td>Erasable, Programmable, Read-Only Memory</td>
</tr>
<tr>
<td>EER</td>
<td>Energy Efficiency Ratio</td>
</tr>
<tr>
<td>EIA</td>
<td>Electronic Industries Association</td>
</tr>
<tr>
<td>EMD</td>
<td>Electromotive Division, General Motors Corporation</td>
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<tr>
<td>EMC</td>
<td>Electro-magnetic Compatibility</td>
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<tr>
<td>EMI</td>
<td>Electro-magnetic Interference</td>
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<td>EP</td>
<td>Electro-pneumatic</td>
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<td>EWL</td>
<td>Equivalent Wheel Load</td>
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<td>F</td>
<td>Fahrenheit</td>
</tr>
<tr>
<td>FAI</td>
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<td>FDA</td>
<td>Food and Drug Administration</td>
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<tr>
<td>FDB</td>
<td>Fahrenheit Dry Bulb</td>
</tr>
<tr>
<td>FEA</td>
<td>Finite Element Analysis (Stress Analysis)</td>
</tr>
<tr>
<td>fpm</td>
<td>Feet Per Minute</td>
</tr>
<tr>
<td>FRA</td>
<td>Federal Railroad Administration</td>
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<tr>
<td>FTA</td>
<td>Federal Transit Administration</td>
</tr>
<tr>
<td>FWB</td>
<td>Fahrenheit Wet Bulb</td>
</tr>
<tr>
<td>g</td>
<td>Acceleration due to gravity (386.1 inches per second per second)</td>
</tr>
<tr>
<td>GE</td>
<td>General Electric Co.</td>
</tr>
<tr>
<td>GFI</td>
<td>Ground Fault Interrupter</td>
</tr>
<tr>
<td>GP</td>
<td>General Purpose</td>
</tr>
<tr>
<td>HCFC</td>
<td>Hydro chlorofluorocarbon</td>
</tr>
<tr>
<td>HD</td>
<td>High Density</td>
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<tr>
<td>Hg</td>
<td>Mercury</td>
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<td>HEP</td>
<td>Head End Power</td>
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<tr>
<td>HST</td>
<td>High Speed Train set</td>
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<tr>
<td>HVAC</td>
<td>Heating, Ventilation and Air Conditioning</td>
</tr>
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<td>Hz</td>
<td>Hertz</td>
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<td>IACS</td>
<td>International Annealed Copper Standard</td>
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<td>IC</td>
<td>Integrated Circuit</td>
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<td>I/C</td>
<td>Intercom</td>
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<td>Insulated Cable Engineers Association</td>
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<tr>
<td>IEC</td>
<td>International Electro technical Commission</td>
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<tr>
<td>IEEE</td>
<td>Institute of Electrical and Electronic Engineers</td>
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<tr>
<td>IGBT</td>
<td>Insulated Gate Bi-polar Transistor</td>
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<td>IITS</td>
<td>Intermittent Inductive Train Stop System</td>
</tr>
<tr>
<td>I/O</td>
<td>Input/Output</td>
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<tr>
<td>IPC</td>
<td>Institute of Printed Circuits</td>
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<tr>
<td>ISO</td>
<td>Organization for Standardization</td>
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<tr>
<td>JEDEC</td>
<td>Joint Electronic Device Engineering Council</td>
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<tr>
<td>Acronym</td>
<td>Description</td>
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<tr>
<td>JHP</td>
<td>Jacketed Hollow Point</td>
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<tr>
<td>kV</td>
<td>Kilovolts</td>
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<tr>
<td>LAHT</td>
<td>Low Alloy High Tensile Strength (Steel)</td>
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<tr>
<td>LCD</td>
<td>Liquid Crystal Display</td>
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<tr>
<td>LED</td>
<td>Light Emitting Diode</td>
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<tr>
<td>LLRU</td>
<td>Lowest Level Replaceable Unit</td>
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<tr>
<td>L/V</td>
<td>Lateral/Vertical</td>
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<tr>
<td>MAP</td>
<td>Maintenance Analysis Program</td>
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<tr>
<td>MCB</td>
<td>Main Circuit Breaker</td>
</tr>
<tr>
<td>MCM</td>
<td>Thousand Circular Mills (wire gauge cross-sectional area)</td>
</tr>
<tr>
<td>MHZ</td>
<td>Megahertz</td>
</tr>
<tr>
<td>MIL</td>
<td>Military Specification</td>
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<tr>
<td>MPH</td>
<td>Miles per Hour</td>
</tr>
<tr>
<td>MPHPSPS</td>
<td>Miles per Hour per Second per Second</td>
</tr>
<tr>
<td>MPU</td>
<td>Machine Room Power Unit</td>
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<tr>
<td>MRB</td>
<td>Material Review Board</td>
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<td>MS</td>
<td>Military Standards</td>
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<td>MS</td>
<td>Margin of Safety</td>
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<td>MSDOS®</td>
<td>Disc Operating System</td>
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<tr>
<td>MTBF</td>
<td>Time between Failures</td>
</tr>
<tr>
<td>N/A</td>
<td>Not Applicable</td>
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<tr>
<td>NAL</td>
<td>Net Axle Lateral Force</td>
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<td>Bureau of Standards</td>
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<td>Northeast Corridor</td>
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<td>Electrical Manufacturers Association</td>
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<td>No Field Lubrication</td>
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<td>National Fire Protection Association</td>
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<td>NIST</td>
<td>National Institute of Standards and Technology</td>
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<td>Net Shoe Force</td>
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<td>Notice to Proceed</td>
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<td>Transportation Safety Board</td>
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<td>OEM</td>
<td>Original Equipment Manufacturer</td>
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<tr>
<td>OFE</td>
<td>Oxygen-Free, Electronic</td>
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<td>OSHA</td>
<td>U.S. Occupational Safety and Health Administration</td>
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<tr>
<td>PA</td>
<td>Public Address</td>
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<tr>
<td>PA/IC</td>
<td>Public Address and Intercom</td>
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<tr>
<td>PC</td>
<td>Personal Computer</td>
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<td>PCMCIA</td>
<td>Personal Computer Memory Card International Association</td>
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<tr>
<td>PIV</td>
<td>Peak Inverse Voltage</td>
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<tr>
<td>ppm</td>
<td>Parts Per Million</td>
</tr>
<tr>
<td>PROM</td>
<td>Programmable Read Only Memory</td>
</tr>
<tr>
<td>psi</td>
<td>Pounds Per Square Inch</td>
</tr>
<tr>
<td>psig</td>
<td>Pounds Per Square Inch Gage</td>
</tr>
<tr>
<td>PT</td>
<td>Potential Transformer</td>
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<tr>
<td>PTS</td>
<td>Position Transducer System</td>
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</table>
PTU Portable Test Unit
PVC Polyvinyl Chloride
QA Quality Assurance
QC Quality Control
RC Resistor Capacitor
RF Radio Frequency
RFI Radio Frequency Interference
RMS Root Mean Square
RQMS Ride Quality Measuring System
SAE Society of Automotive Engineers
SCCO Speed Control Cut Out
SCFM Standard Cubic Feet Per Minute
SDD Software Design Description
SFE SEPTA-Furnished Equipment
SMMS SEPTA Material Management System
SMT Surface Mount Technology
SPL Sound Pressure Level
SSP System Safety Program
ST Sound Transmittant
TBD To Be Determined
TCS Temperature Control Switch
TEFC Totally Enclosed Fan Cooled (Motor)
TGMS Track Geometry Measuring System
THD Total Harmonic Distortion
TIR Total Indicated Run out
T/R Transmitter/Receiver
TTC Transportation Test Center (AAR facility at Pueblo, CO)
TXV Thermal Expansion Valve
UA Heat Transfer
UHF Ultra High Frequency
UL Underwriters Laboratories, Inc
UMTA Urban Mass Transportation Administration
UNC Unified National Coarse
UNR Unified National Round
UPS Uninterruptible Power Supply
USASI United States of America Standards Institute
USDA United States Department of Agriculture
USDOT United States Department of Transportation
USPHS United States Public Health Service
UV Ultra Violet
Vi Initial Velocity
VAC Volts Alternating Current
VDC Volts Direct Current
VHF Very High Frequency
VHS Video Home System
VOM Volt-Ohm Meter
1.24 DEFINITIONS

Definitions and terms used within this Specification shall have the following meanings:

**Analysis** means a logical thought process which includes: clearly stated assumptions which can be justified, calculations with references for methods and equations stated, using data from simulation or, preferably, full-scale test, and clearly-stated conclusions which logically follow from the supporting calculations and data.

**Anti-Climber** means those parts of the ends of adjoining the locomotive units that are designed to engage (when the units are subjected to large buff loads) to prevent climbing and subsequent telescoping of one vehicle into another.

**Arc Chute** means a pathway designed to contain and channel ionized discharged electrical energy harmlessly.

**Automatic Circuit Breaker** means a device for use in an electrical circuit which opens the circuit at a preset current level, providing over-current protection to loads in the circuit, and which is capable of being restored without replacement.

**Axle Sum Ratio** means the sum of the L/V ratios for the two wheels on an axle.

**Brake, Air** means a combination of devices operated by compressed air, arranged in a system, and controlled manually or pneumatically, by means of which the motion of a car or locomotive is retarded or arrested.

**Brake Control System** means the components including software that either automatically or under the control of the engineer cause changes in the retarding force applied to the train by the brake system.

**Brake, Conventional Air** means an air brake system designed in accordance with the current Manual of Standards and Recommended Practices of the Association of American Railroads.

**Brake, Disc** means a retardation system used on some rail vehicles, primarily passenger equipment, which utilizes flat metal discs as the braking surface. Instead of the wheel tread.

**Brake, Electric** is a general term covering both rheostatic and regenerative braking.

**Brake, Regenerative** means braking in which kinetic energy is converted to electrical energy in the traction motors, transferred by the control system through the DC link, and returned to the contact line.
Brake, Rheostatic means braking in which kinetic energy is converted to electrical energy in the traction motors, transferred by the control system through the DC link, and dissipated in resistors on the locomotive.

Cab means that portion of the superstructure of the locomotive designed to be occupied by the crew operating the train.

Cab, controlling means the cab from which the engineer exercises control over the train.

Cant Deficiency means the distance - deficiency is the amount of superelevation (cant) below the amount required for the resultant force vector to be normal to the plane of top of rail for any given speed in a curve.

Car, Passenger means a rail vehicle designed and used to transport passengers.

Collapse means large deformations or buckling of structural members when their yield or buckling strength is exceeded.

Collision Posts mean members of the end structure projecting upward from the under frame to provide protection of occupied compartments from penetration during a collision.

Contractor means the successful offeror for this contract after award.

Corner Post means a rail vehicle structural member that extends vertically from the floor support structure to the roof support structure, located at the intersection of the front or rear surface with the side surface of the vehicle. Corner posts may be part of the end structure.

Crash Energy Management System means structural design techniques whereby unoccupied compartments or volumes of a rail vehicle are designed to be less strong than occupied compartments’ or volumes. The weaker compartments are designed to collapse in a controlled fashion to absorb or dissipate as much of the collision energy as possible.

Crush Distance means the distance a locomotive is shortened due to a collision.

Crush Force means the force causing a locomotive to be shortened during a collision.

Crew Member means an SEPTA employee involved in the on-board operation of the train.

Disc Brake Rotor means a rotating disc attached to a wheel or axle which absorbs friction braking energy.

Emergency Application means a brake application resulting in the maximum retarding force available from the train brake system.

End Structure is the framing and sheathing closing off the ends of the body. The framing may include collision and corner posts, a structural shelf, and members supporting the tops of the collision posts.
Flammability means the ease with which a material ignites and, once ignited, continues to burn.

Day means calendar day.

Front End means the end of a vehicle or rolling stock unit facing the direction of travel.

Full-Scale Simulation is an analysis which solves the equations which describe the behavior of a system. The simulations typically are dynamic, non-linear, and have many degrees of freedom, and so are usually performed with computers.

Full-Scale Test is a test of a production article.

Full-Service Application means a brake application which results from one or more brake pipe reductions sufficient in amount to cause a full service reduction.

Glazing, End Facing means a glazing panel where a line perpendicular to the exterior surface of the panel makes an angle of 50 degrees or less with the longitudinal center line of the locomotive.

Glazing, Exterior means a glazing panel that is an integral part of the exterior skin of the locomotive with a surface exposed to the outside environment.

Glazing Frame means the arrangement used to install the glazing into the structure of the locomotive.

Glazing, Interior means a glazing panel with no surface exposed to the outside environment and which is protected from projectiles by the structure of the locomotive.

Glazing, Side Facing means a glazing panel where a line perpendicular to the exterior surface of the panel makes an angle of more that 50 degrees with the longitudinal center line of the locomotive.

Handrail means safety appliances installed on either side of locomotive exterior doors to assist the crew to safely board and depart.

Head End Power means power generated aboard the locomotive to supply HVAC, lighting, and other electrical loads of the passenger vehicles.

Hunting means locomotive body and/or truck oscillations.

Inshot means a feature in a brake system which produces sufficient brake cylinder pressure that result in zero clearance between brake shoes and wheels and/or disc pads and brake discs.

Lighting Arrestor means a device designed to shunt lightning current to ground.

Longitudinal means in a direction parallel to the normal direction of travel of a vehicle.
L/V Ratio means the ratio of lateral force to vertical force at the interface of the wheel and rail.

Major Equipment shall be defined as follows: traction equipment; auxiliary power equipment; locomotive body; truck; brakes; couplers/drawbars and draft gear; HVAC system and controls; train lines; seats; locomotive diagnostic system; and lighting.

Net Axle Lateral Load means the sum of the forces exerted on the rails by the two wheels on an axle.

Over-Ride means a vehicle or unit climbs over the normal coupling and anti-climbing mechanism and impacts the end of the adjoining vehicle or unit above the under frame.

Permanent Deformation means a structural member undergoes a permanent change in shape.

Program means the process of procurement, design, construction, testing, acceptance and warranty support of high-speed electric locomotives for SEPTA service.

Safety Appliance means an appliance, including but not limited to, handholds, handrails, or ladder treads, made of steel or a material of equal or greater mechanical strength and used by railroad employees to provide a means for safely coupling, ascending, or descending railroad vehicles.

Safety-Critical Item means any item or system that affects the safety or health of any person in or near the train.

Service-Proven refers to locomotives components or systems, and means that these items offer a demonstrated history of satisfactory performance in intercity rail service with a high level of availability under duty cycle and environmental conditions similar to those encountered in SEPTA operations.

Shock Absorbing Material means the material that shall, when impacted, retard and dissipate the energy of an impact force in a manner that does not cause damage or injury.

Side Frame Posts means the main vertical structural framing members in the sides of a vehicle.

Side Sills are the longitudinal rails which form the bottom chord of the side frames.

Software Safety Plan means a controlled, orderly process to develop, produce, test, and verify safe and reliable computer programs for the locomotive.

Spall means to have small pieces of a solid substance dislodged from its surface by the action of mechanical or thermal forces.

Spall Shield refers to a soft elastic transparent coating applied directly to the interior surface of the front windshields.

Static End Load means a compressive force applied to the ends of a locomotive body structure.
Static End Yield Strength means the static end load which just produces the first yielding in the locomotive body structure.

Static Vertical Axle Load means the sum of the vertical forces exerted by an axle of a high speed electric locomotive vehicle when stationary on tangent, level track.

Subcontractor means a supplier of material to the Contractor.

Supplier means a supplier of material to the Contractor.

System Safety Program means a document that SEPTA requires of the Contractor that gives the details of the techniques, procedures and tests to be used as part of the locomotive design process to ensure that the locomotive meets all Federal Safety Standards and SEPTA safety design requirements.

Telescope means a condition where a locomotive body overrides that of an adjoining vehicle and penetrates its interior due to compressive forces arising from a collision.

Transverse means in a direction perpendicular to the normal direction of travel of a vehicle.

Ultimate Strength means the limit of the ability of a structural member to resist fracture or collapse by buckling.

Uncoupling Mechanism means the arrangement for operating the coupler lift lock.

Underframe means the horizontal structure at the bottom of a locomotive body which supports the floor, and to which the superstructure is attached.

Unoccupied Space means the sections of the locomotive which are not normally occupied by the crew.

Witness Plate means a thin foil placed behind a piece of glazing undergoing impact test. Any material spalled or broken from the back side of the glazing shall dent or mark the witness plate.

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THIS PAGE IS INTENTIONALLY BLANK
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 Bardagjy 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 mph/sps, 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)
a. 7.5 seconds maximum - train length, 3-6 cars
b. 26.0 seconds maximum - train length, 18 cars

3. Emergency Application - (95% of commanded brake):
   a. 4.0 seconds maximum - train length, 3-6 cars
   b. 4.75 seconds maximum - train length, 18 cars

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</th>
</tr>
</thead>
<tbody>
<tr>
<td>125 mph</td>
<td>7,717 ft</td>
<td>2.5 mphs</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 mphps and the maximum instantaneous brake rate shall not exceed 2.5 mphps. 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 mphs</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 mphps and the maximum instantaneous brake rate shall not exceed 2.7 mphps.

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>
### Pin Function Table

<table>
<thead>
<tr>
<th>Pin No.</th>
<th>Function</th>
<th>Marker</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>Doors Open - Left Side</td>
<td>BOB</td>
<td>12</td>
</tr>
<tr>
<td>16</td>
<td>Doors Close - Right Side</td>
<td>ACB</td>
<td>12</td>
</tr>
<tr>
<td>17</td>
<td>Doors Close - Left Side</td>
<td>BCB</td>
<td>12</td>
</tr>
<tr>
<td>18</td>
<td>Engineman Door Close Light</td>
<td>EL</td>
<td>12</td>
</tr>
<tr>
<td>19</td>
<td>Brake Release Light</td>
<td>BR</td>
<td>12</td>
</tr>
<tr>
<td>20</td>
<td>Brake Applied Light</td>
<td>BA</td>
<td>12</td>
</tr>
<tr>
<td>21</td>
<td>Doors Open – Left Side Low Level</td>
<td>DOLL</td>
<td>12</td>
</tr>
<tr>
<td>22</td>
<td>Conductor’s Signal Buzzer</td>
<td>CS</td>
<td>12</td>
</tr>
<tr>
<td>23</td>
<td>Conductor’s Signal Light</td>
<td>CL</td>
<td>12</td>
</tr>
<tr>
<td>24</td>
<td>Audi 2</td>
<td>PA7</td>
<td>12 Shielded</td>
</tr>
<tr>
<td>25</td>
<td>Audio 2</td>
<td>PA8</td>
<td>12 Shielded</td>
</tr>
<tr>
<td>26</td>
<td>Positive Signal</td>
<td>PS</td>
<td>12</td>
</tr>
<tr>
<td>27</td>
<td>Doors Open – Left Side High Level</td>
<td>DOLH</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>Car hot Journal</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:

<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>
</tbody>
</table>
## Pin Function | Marker | Size
---|---|---
12 | B Valve | BV | 12
13 | Positive Control | PC | 10
14 | Pantograph Down | P.D. | 12
15 | A Valve | AV | 12
16 | Engine Run | ER | 12
17 | Pantograph Up | PU. | 12
18 | VC 25 KV - 60 Hz | VC | 12
19 | Excessive Current | E.C. | 12
20 | Brake Warning | BW | 12
21 | Brake System Negative | BN. | 12
22 | Emergency Brake | EM. | 12
23 | Manual Sanding | MS | 12
24 | Brake Application | BA. | 12
25 | Brake Release | BR. | 10
26 | Reset Fault | RF | 12
27 | No Power Brake | NPB | 12

** 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.

### APTA RP-E-015-99 Figures

<table>
<thead>
<tr>
<th>Figure #</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Applies</td>
</tr>
<tr>
<td>2</td>
<td>Applies</td>
</tr>
<tr>
<td>3</td>
<td>Not Applicable</td>
</tr>
<tr>
<td>4</td>
<td>Applicable, except no &quot;C&quot; contacts required</td>
</tr>
<tr>
<td>5</td>
<td>Applies</td>
</tr>
<tr>
<td>6</td>
<td>Applies</td>
</tr>
<tr>
<td>7</td>
<td>Applies</td>
</tr>
<tr>
<td>8</td>
<td>Applicable, except for no F-End isolation switch or engine layover heater</td>
</tr>
<tr>
<td>9</td>
<td>Not Applicable</td>
</tr>
<tr>
<td>10</td>
<td>Applies</td>
</tr>
<tr>
<td>11</td>
<td>Applies</td>
</tr>
</tbody>
</table>

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

| 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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3 LOCOMOTIVE CARBODY STRUCTURE

3.1 GENERAL

The locomotive carbody structure shall consist of a roof, side frames, underframe, and end frames. The structural design shall be based on the specified loads, deflections, factors of safety, and the test requirements. The finished locomotive structure shall be proof-tested in accordance with Section 16.5.19 to validate the design analysis. As a minimum, the testing and results shall be per the latest version of APTA SS-C&S-034-99 Section 8 or 49 CFR 229, whichever is most severe.

The locomotive carbody structure and attached equipment shall be designed to provide clearances to the track and wayside structures in accordance with Amtrak Drawing D-05-1355, Rev E. Clearance shall be maintained with any one defective suspension component, worst case wear and dynamic motion on tangent or curved track.

The locomotive carbody structure shall be designed to accommodate the equipment "clean-air" system required by Section 9.6.5. The clean-air system supplies filtered cooling air through ducts to the heat-generating and/or arc-producing electrical equipment. Exterior grilles for the clean air and HVAC systems shall be of a design which enhances the exterior appearance of the locomotive. Exterior panels for the purpose of access to major locomotive equipment shall be easily removable and weather tight. Drainage shall be provided for all cavities to prevent retention of water.

The locomotive carbody structure shall be designed to accommodate the brackets and secondary structures necessary to install equipment. Heat shields, as required, shall be provided for resistors and other heat-generating equipment in order to avoid damage to, or reduction in service life of adjacent components or structure. Details of the design arrangement and installation of the carbody equipment and apparatus shall be submitted to Drawing for review and approval.

A locomotive aisle, or aisles, from cab bulkhead to cab bulkhead, shall be sufficient to provide a safe passage for the crew and access for maintenance and module removal from inside the machine room. There shall be no sharp edges, corners or tripping hazards any place in or on the vehicle where crew or maintenance personnel may come into contact with such conditions. The vehicle shall be in compliance with 49 CFR 238.233(e) and AAR MSRP Section M, Recommended Practices, 5107, 5115, 5124, 5120, 5122, 5126, 5127, 5128, 5136 and 5137. These requirements shall apply to equipment or components furnished by suppliers as well as to the Contractor's own manufacture.

The Contractor shall provide methodology for maintaining uniform vehicle appearance over the life of the equipment, and a life cycle cost analysis

The locomotive shall be equipped with AEI tag, located per AAR specification
3.2 MATERIALS

The locomotive shall be constructed of low-alloy, high-tensile (LAHT) steel, approved equal, or austenitic stainless steel AISI type 201L or 301L in accordance with Section 15.5 and 15.6. End underframes shall be constructed of weld-fabricated low-alloy, LAHT steel. The underframes and end frames may be constructed of weld-fabricated LAHT steel or stainless steel. Structural welding shall be in accordance with Section 15.4.2. Aluminum shall be to the requirements of Section 15.8 and shall not be used for load carrying structural members. Aluminum shall only be used when agreed to in writing by Drawing. The use of polyurethane insulation or asbestos is prohibited. All carbody structural material shall be suitably marked on an unexposed surface with the ASTM designation to aid future recycling.

3.3 CONSTRUCTION METHODS

Where LAHT steel is used, as in the end underframes, the primary car structure shall be joined by welding, using connections designed in accordance with AWS D1.1 (2006) or other approved equal standard. Where stainless steel is used, assembly shall be by resistance welding. All welding shall conform to the requirements of Section 15.4 including notch-toughness testing of welded samples. Bolts, rivets, or welding may be used to join secondary structure and for attaching brackets and equipment for primary structure. Refer to Section 15.3 for joining requirements. Where dissimilar metals are joined, the metals shall be protected against electrolytic corrosion in accordance with the requirements of Section 15.8.3. Rivets or bolts used in combination with welds in a connection shall not be considered as sharing the load with the welds; welds shall be designed to carry the entire load across the connection.

Connections between structural members of the car shall be made so that the design strength of the connection shall exceed the ultimate strength of the weaker member. This requirement applies only to connections between carbody structural members, in and around crew compartments, which are important in the specified emergency load cases. These load cases include the end loads, end-frame loads, side loads, and roll-over loads. The ultimate strength of the weaker member is obtained by overloading the member at the location of the emergency load case.

Cosmetic aspects of the carbody are of great importance to SEPTA. The Contractor shall be responsible for manufacturing techniques to fabricate flat carbody surfaces. The Contractor shall also control and properly support large assemblies during repositioning, lifting, storing or moving such assemblies so as not to cause flexing that will enable or cause distortions or un-flat conditions of the assembly to occur. All sheet metal exposed to view (side, end, and roof sheathing) shall be as smooth as possible on the outside with a maximum variation from a straight line on flat surfaces, measured in any direction, of 0.0984 inch gradual discontinuity over 36 inches and 0.0625 inch within a distance of 12 inches on the sides of the car. For the roof, deviations of 0.1875 inch over a 36 inch span and 0.125 inch over a distance of 12 inches will be allowable provided the area involved cannot be seen from the platform level. For conditions where discontinuities within the flatness form wave or rippling effects, acceptance criteria shall be based on not exceeding 0.0625 inches across the patterned area under any distance. This requirement applies to the vehicle in the ready-to-run condition. Dents, gashes, or other surface imperfections shall not be permitted.
For side, end, and roof sheathing, spacing of resistance and spot welds shall be according to approved structural drawings. Spacing shall not exceed two (2) inches plus twice the weld nugget diameter for any structural application, including car body side sheets, roof sheets, and corrugation. Additionally, there shall be two or more spot welds per node for attaching corrugated panels to framing members. Each resistance spot weld shall blend in with the cosmetics of the car in terms not affecting the flatness around the weld (pillowing) and/or contain discoloration. Resistance weld samples, 8-1/2 inch by 11 inch, shall be submitted, and include a minimum of six (6) welds.

Uniform construction and assembly methods shall permit interchangeability of like subsystems, equipment and parts. The Contractor shall verify that this requirement is met as part of the Contractor Quality Assurance Program. The proposed construction tolerances of the finished vehicle shall be submitted to Drawing for review.

3.4 STRUCTURAL DESIGN

The locomotive structure shall consist of two side frames, an underframe, two end frames and a roof. The side frames consist of posts, horizontal rails, and sheathing. The underframe consists of end underframes, including draft gear housings, bolsters, side sills, cross bearers, floor beams, under-floor shear panels, sub-floor pans, and an optional center sill. The end frames consist of corner posts, collision posts, a structural shelf, a top cross member and sheathing. The roof shall consist of carlines and, if necessary, longitudinal purlins, covered with corrugated or smooth sheathing. Structural Design shall be in accordance with 49 CFR parts 229, 238 and 5580.

3.4.1 Underframe

The underframe shall consist of two end underframes, two body bolsters, two side sills, a center sill (optional), cross-bearers; floor beams, sub-floor pans, and under-floor shear panels, if required.

3.4.1.1 Side Sills

Side sills extending between ends shall be provided on both sides of the structure. They shall be fastened to floor beams, cross-bearers, bolsters, end sills and under-floor shear panels. The side sills shall be used to partially resist the longitudinal loads and other loads as required by this specification. The connections of the side sills to the end sills, bolsters, and under-floor shear panels shall be designed to resist all such loads transmitted from those members to the side sills.

3.4.1.2 Body Bolster

The body bolster shall be designed to transmit the specified vertical and horizontal loads from the trucks into the body, and, if no center sill is used, to transmit the longitudinal loads from the draft sill into the side sills. The design shall provide clearance for all truck positions, strength of truck attachment, and accessibility for truck maintenance and removal.
3.4.1.3 Center Sill

The center sill, if provided, shall extend between the bolsters. The center sill shall be connected to an extension of the draft sill ("draft-sill stubs") at the inboard sides of the body bolsters, and to the transverse floor beams, and shall be connected to and braced by crossbearers.

3.4.1.4 Cross-bearers and Floor Beams

Cross-bearers, as required, shall be provided both to stabilize the center sill (if used) and to transmit any vertical loads from the center sill to the side frames. If a stainless steel structure is supplied, the cross-bearers shall be of stainless steel. Floor beams, spaced to limit floor panel deflection, shall be provided. Floor stiffness shall be as specified in Section 3.5.7. Floor panels shall be as detailed in Section 4.4.4.

3.4.1.5 Jacking Pads

Jacking pads are required on each locomotive. There shall be one at each end of each body bolster, for a total of four per vehicle. The pads shall extend one-half to one inch below the bottom of the side sill. The pad location and lifting procedure shall be submitted to Drawing for review and approval.

The locomotives shall be designed to permit jacking of either end for truck removal or re-railing, with the opposite end resting on its truck without damage to the truck attachment, underframe, or any of the under floor apparatus. If trucks cannot be removed in this manner, a procedure to accomplish truck removal, subject to Drawing approval, must be provided. Any required specialized tools or equipment must be supplied. Refer to Section 3.5.9 for load requirements.

3.4.1.6 Truck to Carbody Structure Connection

The connection between the truck and carbody structure shall be designed so that the trucks are locked to and raised with the carbody structure unless intentionally detached there from. Elements of the truck connection shall not interfere with the operation of normal suspension elements for any possible condition of shimming for wheel wear or a low coupler. Refer to Section 3.5.10.1 for load requirements.

3.4.1.7 End Underframe

An end underframe, including but not limited to the draft sill, end sill, draft gear pocket, and coupler support structure shall be provided at the end of each structure and shall be made of low-alloy, high-tensile steel conforming to the requirements of Section 15.6.

The end underframe shall be assembled by arc welding in accordance with Section 15.4. Any joints stressed in tension or compression directly by the specified design or test loads shall be AWS pre-qualified complete-joint-penetration groove-welded joints. All other joints may be AWS pre-qualified, partial-joint-penetration groove-welded joints or welds with total effective throat equal to or greater than the smallest thickness of the pieces joined. The assembly shall be heat treated after welding and other manufacturing processes are completed, if required by the.
material manufacturer for strength, toughness attainment, or stress relief. The end underframe weldment, and connections to adjoining structure, e.g. body bolster, shall provide continuity of flanges and webs at any place where load-bearing members intersect.

### 3.4.1.8 End Sill

The end sill shall consist of the buffer beams, the anti-climbing arrangement and collision post connections, and shall be attached to the draft sill. The collision posts shall extend down to the bottom plate of the end sill and shall be welded to both the top and the bottom plates. If corner post stubs are provided, they shall also be welded to the top and bottom plates.

The end sill shall be designed to transmit the required anti-climber loadings into the collision posts and draft sill without exceeding the yield strength or elastic buckling strength of the end sill structure. It shall also be capable of transmitting into the draft sill the axial and shear forces, and bending moments resulting from the collision and corner post loads specified in Sections 3.5.5, and 3.5.6.

### 3.4.1.9 Anti-Climbing

A ribbed anti-climber designed to effectively engage existing Drawing equipment including, but not limited to the AEM 7, shall be provided at each end of the locomotive. The anti-climbing arrangement shall be in conformity with 49 CFR 229.141(a) (2), APTA Standard SS-C&S-034-99 Rev 2 Section 5.5 and AAR MSRP S-580, "Locomotive Crashworthiness Requirements", and as provided in Section 3.5.5.

### 3.4.1.10 Draft Sill

The draft sill shall extend longitudinally from the end sill to the body bolster, and shall include the coupler support structure and draft gear pocket. It shall be designed to transmit the specified longitudinal loadings from the anti-climber and coupler into the body bolster. The side sills may carry some of the longitudinal load. The design shall include a critical section that fails preferentially immediately outboard of the coupler support structure, and forward of the seating position of any crew person.

### 3.4.1.11 Coupler Carrier

A coupler carrier shall be provided as part of the end underframe assembly, and shall be designed in accordance with the applicable AAR and FRA requirements and as specified in Sections 3.4.2.2 and 3.5.8. In addition, the coupler carrier and those portions of the carbody to which it is attached shall be designed to support one end of the car, with the truck attached, on the coupler or a fixture that attaches to the anti-climber such as might occur during emergency jacking in the event of a derailment. The coupler carrier element on which the coupler shank slides shall have a 0.25-in thick wear plate of manganese steel welded to it, or a non-metallic wear plate such as Nylatron as approved by SEPTA, unless centering struts are used in order to avoid contact between the coupler and coupler carrier under normal operation. The coupler carrier shall provide a means to adjust coupler height in increments of 0.25-inch. The range of
adjustment shall be sufficient to maintain required coupler height for all carbody-truck configurations.

### 3.4.2 Side Frame

The side frame shall consist of posts, horizontal rails and side sheathing. The side frames shall be designed to incorporate the windows specified in Section 4.7 and doors specified in Section 4.5.

#### 3.4.2.1 Posts

Structural posts shall be at the sides of all door and window openings and elsewhere as required. Full-height structural posts shall be continuous between side sill and roof rail. The side posts section moduli shall meet the requirements of APTA SS-C&S-034-99 Rev 2, Section 5.2.2.1.1 and 49 CFR 229.141.

The side frame shall be locally reinforced as necessary with extra-heavy posts and shear panels to transmit vertical load from the body bolster and crossbearer ends, into the side frame sheathing.

Full-height side frame post spacing shall be compatible with the side window and door arrangement specified in Sections 4.12 and 4.7, respectively. Side post spacing shall be selected so as to minimize out-of-plane distortions in the side sheathing due to welding and fabrication processes. The spacing shall also be selected to minimize elastic buckling of the side sheathing for all specified loading conditions.

#### 3.4.2.2 Horizontal Rails

Horizontal rails shall be used at the top and bottom of the side frames, above and below the windows, and elsewhere as required. Where horizontal rails are interrupted by posts, gussets shall be used to reinforce the connection to effectively make the rail continuous.

#### 3.4.2.3 Side Sheathing

The side sheet thickness shall meet the thickness requirements of APTA SS-C&S-034-99 Rev 2, Section 5.2.2.1.2 and 49 CFR 238.217b). Side sheets may be stiffened by corrugations or similar sections. Side sheets shall be structurally welded to the outside of the side-frame posts in the space between the side sill and the roof as per Section 3.3.

#### 3.4.2.4 End Frames

End frames shall consist of full height corner posts, collision posts, structural shelf, top cross member and sheathing. End frames shall be designed in accordance with Section 3.5.2, and, in addition, shall be designed to resist without failure normal operating loads and the specified collision and jacking loads.
3.4.2.5 Collision Posts

Two vertical collision posts shall be located at the front and rear of the locomotive on each side of the longitudinal centerline extending upwards from the bottom of the underframe. The posts, including reinforcement to provide the specified shear strength at the floor shall meet all applicable requirements of APTA SS-C&S-034-99 Rev 2 Section 5.3.1, AAR MSRP S-580 Section 6.2, 49 CFR 229.141, and TS 3.5.5.

3.4.2.6 Corner Posts

There shall be structural corner posts at each corner of the car body (body corner posts). Corner posts shall extend full height from the bottom of the underframe to the roof, and shall be reinforced, if required, to meet all applicable requirements of APTA SS-C&S-034-99 Rev 2 Section 5.3.2 and TS 3.5.6.

3.4.2.7 Structural Shelf

The structural shelf shall be a horizontal transverse beam in the front end frame just below the windshield. It shall extend from corner post to corner post and shall be securely attached to all corner and collision posts. The structural shelf shall be designed to resist the loads specified in TS 3.5.7.

3.4.2.8 Lifting Eyes

A minimum of two (2) lifting eyes per carbody end shall be provided at the tops of collision posts or other location as agreed to by Drawing, and may be recessed and covered if necessary for appearance or to minimize drag. The lifting procedure and design shall be submitted to Drawing for review and approval.

3.4.2.9 End Sheathing

End frame sheathing shall be structurally welded to the end structure and comply with APTA SS-C&S-034-99, Rev 2, Section 5.3.4 and AAR MSRP S-580 Section 6.7 or 7.7. Weld spacing criteria shall be no less than as specified in TS 3.3.

3.4.2.10 Top Cross Member

A top cross member shall connect and partially support the top of the full height corner posts, and full height collision posts (if part of the design).
3.4.3 Roof

3.4.3.1 Roof Framing
The roof framing shall consist of carlines (transverse) and purlins (longitudinal), fastened to the side and end framing to obtain a strong, rigid, integrated structure that complies with APTA SS-C&S-034-99 Rev 2, Section 5.4.1. The roof shall be properly reinforced and braced with structural members to carry the weight and vibration due to roof-mounted apparatus.

3.4.3.2 Roof Openings
Openings in the roof shall be provided for fresh air intakes (where required), equipment access and removal, and for electrical apparatus ventilation. Openings shall be framed, reinforced, and weather tight.

3.4.3.3 Roof Sheathing
Roof sheathing shall be either smooth or ribbed as approved by Drawing. The material and thickness selected shall meet the roof load requirements defined in TS 3.5.11. Corrugated austenitic stainless steel roof sheets, if used, shall be minimum 3-hard temper, and a minimum thickness of 0.024 in. Corrugated or smooth aluminum roof sheets, if approved by Drawing, shall have penetration resistance equal to or better than the penetration resistance provided by the specified stainless steel. Weld spacing criteria shall be as specified in TS 3.3.

3.4.3.4 Roof Equipment Arrangement
Roof hatches, if used, shall not exceed 17 ft. and length and lifting lugs shall be spaced no more than 9 ft. longitudinally on the hatch.

To support roof-mounted equipment, brackets shall be welded to the roof on or at carlines or purlins, not on unsupported roof sheathing. The roof equipment shall be bolted to these brackets; through-roof mechanical fasteners shall not be permitted. Refer to TS 3.5.11 and 3.5.13 for additional equipment mounting requirements.

Recesses shall have drains with sufficient capacity to prevent accumulation of water under all possible conditions, including rainfall, car washing, and condensate flow, if the drains are also used for that purpose.

3.4.3.5 Gutters
Water-deflecting gutters shall be installed at the edge of the roof, at a minimum over side-entrance doorways and windows. If full-length gutters are provided, they shall discharge at each side of each side entrance doorway, clear of the doorway and adjacent windows, indicator lights, loop steps, and handholds.
3.4.3.6 Pantograph Support

Supports shall be provided for the pantographs on the locomotives. The frame structure shall be reviewed with the pantograph supplier to minimize redundant frame structural members. A walkway with a non-skid surface shall be provided on the end of the locomotive equipped with pantographs, running the length of the pantograph base along both sides of the pantograph.

3.4.4 Pilot

A pilot meeting the requirements of 49 CFR 229.123 shall be provided at both ends of the locomotive. The pilots shall be attached to the carbody with mechanical fasteners for ease of installation and height adjustment and shall be capable of plowing a minimum of 12 inches of snow. Design loads for the pilot shall be in accordance with TS 3.5.15. The pilot shall cover the entire area below the anti-climber with openings and/or access panels for the trainline hoses and MU cables.

3.4.5 Camber

Locomotives shall be designed and constructed so that, for the lifetime of the locomotive, the camber between bolsters shall be positive, but not greater than 2 inch on a ready-to-run locomotive, and shall not be less than zero under full load.

3.5 DESIGN LOADS AND ALLOWABLE STRESSES

3.5.1 General

The design loads shall include those required by the FRA, APTA, AAR, and this specification. Allowable stress shall be the most restrictive of that indicated in the applicable FRA, APTA, AAR standard or this specification. Elastic buckling is permissible for any loading condition but under no circumstances shall plastic buckling be permitted for any elastic test criteria (no permanent deformation). Additionally for load cases with elastic test criteria highly localized yielding which does not otherwise compromise the ability of the affected structure to meet the requirements of the specification shall be considered on a case-by-case basis.


Locomotives shall comply with applicable Federal Statutes and Federal regulatory standards for railroad safety, provided that the more stringent requirements contained in this specification shall govern.
3.5.2 Crashworthiness

3.5.2.1 General
For effective crashworthiness, the locomotive structure shall be designed to maximize energy-absorbing capability within the specified static strength parameters per APTA SS-C&S-034-99 Rev. 2. During the energy absorbing phase, the smoothed crushing force shall exhibit monotonically non-decreasing behavior which means the absorbed energy curve should be constantly increasing, without any sudden or abrupt decreases, during time of a collision. While the total energy absorbed would be all of the area under the curve, it is important that the rate of energy absorption be steadily increasing. This translates into a smooth deceleration for the occupants.

As an option to fulfill FRA crashworthiness requirements, the Contractor may include Crash Energy Management (CEM) elements. The Contractor may elect to meet the collision and corner posts strength and energy absorption requirements in accordance with Appendix F of 49 CFR Part 238 in lieu of the requirements of either 49CFR 238.211 (Collision Posts) or 49 CFR 238.213 (Corner Posts), or both.

3.5.2.2 Roll-Over Strength
Locomotives shall be designed to rest on their sides, as per APTA SS-C&S-034-99 Rev 2, Section 5.2.2.2.1. The allowable stress for this condition shall be one-half yield or one-half the critical buckling stress, whichever is less.

Locomotives shall be designed to rest on their roofs as per APTA SS-C&S-034-99 Rev 2, Section 5.4.2 and 49 CFR 238.215b. Other than roof sheathing and framing, the allowable stress for this condition shall be one-half yield or one-half the critical buckling stress, whichever is less.

3.5.2.3 Vertical Operating Load
The completely equipped carbody shall be designed to carry the vehicle weight with full crew load, less truck weight, distributed per the expected equipment and crew positions, with stresses not exceeding 50% of the guaranteed minimum material yield strength, or the buckling strength, whichever is less.

For each joint of the carbody bolster and attachment joints to the carbody bolster, the static stress with full load shall be less than the mean stress that determines the allowable fatigue endurance limit.

The fatigue stress range shall be computed by multiplying the static stress at the ready to run plus crew load by the dynamic factor (fatigue load range). The dynamic factor shall be determined by the Contractor but shall not be less than +/-0.40. This stress range shall be within the allowable fatigue endurance limit obtained from AAR MSRP C-11, Section 7.4, or AWS D1.1 (2006), Section 2 with the endurance limit taken at 10 million cycles. The Contractor shall use allowable fatigue stresses from its own tests for:
1. Joint designs not covered by AAR MSRP C-11, Section 7.4 or AWS D1.1 (2006), Section 2, and

2. Joint designs covered by AAR MSRP C-11, Section 7.4 or AWS D1.1 (2006), Section 2, if the Contractor's allowable stresses are more conservative than AAR and AWS allowables.

3.5.2.4 End Compression Load

The vehicle shall be designed to meet the end compression load per APTA SS-C&S-034-99 Rev 2 Section 5.1, AAR MSRP S-580 Section 8.2, and FRA 49 CFR 229.141.

3.5.2.5 Collision Post Load

Collision posts shall be designed to meet APTA SS-C&S-034-99 Rev 2, Section 5.3.1.2.1, AAR MSRP S-580, Section 8.3 as appropriate, and FRA 49 CFR 238.211.

Collision posts and supporting structure in the underframe and end frame shall be designed so that when a post is overloaded, the initial failure shall begin as bending or buckling in the post. The connections of the posts to the supporting structure, and the supporting structure, shall support the posts at their ultimate capacity. The ultimate shear and tensile strength of the connection fasteners and welds shall exceed that required by any deformation to ensure that shear and tensile failure of the fasteners and welds shall not occur, even with severe deformation of the collision posts and of the top connecting and supporting structural elements. Overload of the collision post bottom connections shall result in buckling and crushing of the underframe structural members to which the collision posts and any collision post reinforcements are attached, rather than shearing or fracturing of the posts.

3.5.3 Corner Post Load

Corner posts shall be designed to meet APTA SS-C&S-034-99 Rev 2, Section 5.3.2.2, and AAR MSRP S-580, Section 7.6 or 8.4 as appropriate.

Corner posts and supporting structure in the underframe and end frame shall be designed so that when a post is overloaded, the initial failure shall begin as bending or buckling in the post. The connections of the posts to the supporting structure, and the supporting structure, shall support the posts at their ultimate capacity. The ultimate shear and tensile strength of the connection fasteners and welds shall exceed that required by any deformation to ensure that shear and tensile failure of the fasteners and welds shall not occur, even with severe deformation of the corner posts and of the top connecting and supporting structural elements. Overload of the corner post bottom connections shall result in buckling and crushing of the underframe structural members to which the corner posts and any corner post reinforcements are attached, rather than shearing or fracturing of the posts.
3.5.4 Structural Shelf Load
The structural shelf shall support a minimum longitudinal load of 15,000 pounds force applied anywhere along the span, without permanent deformation of any part of the vehicle structure. The load shall be applied evenly along the shelf height and a width of no more than 4 inches.

3.5.5 Anti-Climbing Load
A ribbed anti-climber shall be applied to each end of the locomotive and shall resist a vertical load of not less than 200,000 pounds without exceeding the ultimate strength of the anti-climber, the car body structure, and the connection of the anti-climber to the carbody structure in compliance with APTA SS-C&S-034-99, Rev 2 Section 5.5.3 and 49 CFR 229. The required analyses of anti-climber strength shall assume engagement of one less than the total number of ribs on mating anti-climbers. If the locomotive end is designed to crush and absorb energy in a controlled manner in accordance with the requirements of TS 3.4.2, then, alternatively, the initial vertical ultimate strength of the anti-climber prior to structural crushing may be less than 200,000 pounds, provided:


2. The vertical ultimate strength is not less than 200,000 pounds at the full amount of controlled crushing for which the crushable end module is designed in compliance with APTA SS-C&S-034-99 Rev 2, Section 5.5.3, and 49 CFR 229.

3.5.6 Side Impact Load
The vehicle body structures shall be designed to resist an inward-directed load of 40,000 lbf applied to the side sill, over the full vertical dimension of the specified member for a distance of 8 feet along the vehicle length in accordance with APTA SS-C&S-034-99 Rev 2, Section 5.2.2.2.2. The allowable stress shall be the lesser of the yield stress and the critical buckling stress with local yielding of the side sill side sheathing allowed.

3.5.7 Floor Load
The design floor load shall be the sum of the weight of all equipment and interior furnishings mounted to the floor. In addition to the requirements of TS 3.5.3, the floor beams shall not deflect more than 1/250 of their span when the distributed design floor load is applied. The floor panels shall not deflect more than 1/250 of their span between floor beams when the distributed design floor load is applied.

3.5.8 Roof Load
The roof shall support the loads of APTA SS-C&S-034-99 Rev 2, Section 5.4 and AAR MSRP S-580 Section 8.11, Longitudinal Roof Load (cant rail load), as appropriate. Additionally, all parts of the roof structure and sheets, roof walkway, screens, and other guards shall have sufficient strength to withstand, without permanent deformation, the loads imposed by a mechanical car washer.
3.5.9 Jacking and Lifting Load

The carbody jack pads and lifting eyes, and supporting carbody structure shall be capable of withstanding, with a load factor of 2, a vertical load equal to the weight of a locomotive with trucks attached equally distributed on the jack pads or lifting eyes, in combination with a horizontal load in any direction of magnitude equal to 10% of the vertical load. The coupler carrier and supporting structures and those portions of the carbody to which they are attached shall be capable of withstanding, with a load factor of 2, a vertical load equal to the weight of a locomotive with the associated truck detached, and the carbody resting on the opposite truck, and a simultaneous horizontal load in any direction equal to 10% of the vertical load. With the above loading, there shall be no permanent deformation.

The carbody, jack pads, and supporting carbody structure shall be capable of withstanding, with a load factor of 1.25, a vertical load equal to the weight of an empty car without trucks attached on any two diagonally-opposite jack pads without permanent deformation of the carbody or the jack pads.

3.5.10 Equipment Load

The design load factor for the mounting of equipment, any portion of the equipment, equipment boxes, equipment hangers, standby supports, safety hangers, and the carbody supporting structure shall comply with APTA SS-C&S-034-99 Rev 2, Sections 5.7.1 and 5.7.3. Equipment mounts shall be designed so the strength of fasteners in tension or the shearing of fasteners through the base material shall not govern strength. Cab seating and interior fittings shall be designed per AAR MSRP S-580 and APTA SS-C&S-011.

Equipment cubicles shall be bolted to the main structure and be easily removed through the roof for major repair or overhaul. Equipment within an equipment box need not meet the above load criteria provided it can be shown that the equipment shall not penetrate the walls of the equipment box when exposed to the above loads. The equipment box shall conform to the above load criteria with the rearranged equipment (i.e., equipment that broke loose) in addition to its normal arrangement.

3.5.10.1 Truck to Carbody Structural Connection Load

An approved truck safety mechanism which locks the completely assembled truck, including the bolster, if used, to the carbody shall be provided in accordance, with the requirements of APTA SS-C&S-034-99 Rev 2 Section 5.6, and 49 CFR 229.141 (a).

3.5.11 Pilot Load

A pilot shall be provided at each end of the locomotive, and be sufficiently strong to perform its intended functions, but, as a minimum, shall be designed to resist the following loads without exceeding the yield strength or elastic buckling strength of the materials used:

1. Longitudinal load at bottom of pilot, at the rail location of 75,000 lb on each side applied simultaneously,
2. Longitudinal load at bottom of pilot, at centerline of locomotive of 50,000 lb,

3. Transverse load, on lower outboard edge of pilot of 50,000 lb, applied separately.

### 3.5.12 Emergency Egress

The Contractor shall incorporate into the carbody design suitable means for the emergency egress of the locomotive engineer. Concepts such as removable roof hatches and/or windshields removable from the inside of the locomotive shall be presented by the Contractor during the design phase for Drawing consideration.

### 3.5.13 Emergency Roof Access

Emergency roof access shall be provided at each cab by means of a conspicuously marked structural weak point in the roof for access by properly equipped emergency response personnel when the locomotive is on its side. Minimum opening shall be 26 inches by 24 inches. Drawing will consider alternative sizes. The ceiling space below the emergency access location shall be free from wire, cabling, conduit and piping. The area shall also be free of any secondary structure. Each location shall be marked with reflective material of contrasting color and caution decals as specified by Drawing.

### 3.6 STRESS ANALYSIS

#### 3.6.1 General

The Contractor shall submit a stress analysis of the carbody structure and of supports for equipment weighing over 150 pounds within 90 days of NTP and a minimum of 60 calendar days prior to commencing manufacture of any carbody structural parts. Stress analyses for supports for items weighing less than 150 pounds may be requested for review at the discretion of SEPTA.

The carbody stress analysis shall consist of a stress analysis plan, structural sketches, finite element model, a linear-elastic Finite Element Analysis (FEA), an analysis of the Crash Energy Management design required in TS 3.5.2, and a manual stress analysis. The stress analysis shall show calculated stresses, allowable stresses, and margins of safety for all structural elements for all specified loading conditions. The approved stress analysis shall be a prerequisite for approval of the structural test procedures required by this specification and shall be used as an aid in determining strain gage locations. Not less than 60 calendar days shall be provided in the Contractor’s schedule for Drawing’s review of the Contractor’s first submittal of its stress analysis, and 30 days for submittal of revised versions.

For any portion of the proposed design which is based on a service-proven vehicle, the Contractor may provide data from previous tests, historical data from operations, or stress analyses as required to satisfy the corresponding portion of these requirements.
3.6.2 Definitions

The definitions for “permanent deformation,” “load factor,” and “margin of safety” shall be per APTA SS-C&S-034-99, Rev 2, Section 3.1.

3.6.3 Stress Analysis Plan

The load cases to be analyzed shall be as per Appendix xxxx and 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, elastic-plastic 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.

If the analysis shall utilize symmetry and anti-symmetry techniques, the plan shall describe all the assumptions and procedures involved in the implementation. The report shall clearly describe how each symmetric and anti-symmetric model is combined to yield calculation results for the total structure, for all the required load cases. Symmetry and anti-symmetry boundary conditions shall be clearly illustrated.

The stress analysis plan must be submitted and approved prior to approval of the stress analysis report required by TS 3.6.6.

3.6.4 Structural Sketch

In order to define the functional members, and method of joining, structural sketches conforming to APTA C&S-034-99 Section 7.2 are required prior to the preliminary finite element model submittal and with the formal presentation of the completed stress analysis report. The Contractor shall submit and receive conditional approval of the structural sketch before submitting the finite element model for approval. Updated structural sketches shall be submitted as required to remain current with the carbody design, and the finite element model in concurrence with Section 2.2.18.

3.6.5 Finite Element Model (FEM)

The Contractor shall submit and receive approval of the finite element model using an industry accepted program such as NASTRAN, ANSYS, or approved equal prior to performing the analysis. The element mesh, all assumptions, and all input data, such as loads, boundary conditions, coupled degrees of freedom, restraint equations, area properties, validations, strain gauge correlations as gained from load cases measured on the railroad and material properties shall be included as part of the model submittal and again as part of the complete analysis. If the model contains shell elements, the report shall include element plots defining the top and bottom surface of each such element. A table shall be included showing the engineering properties (yield strength, ultimate strength, elongation, and Young’s modulus for tension, compression, and shear) of each grade and temper of the material used for the car structure. These values shall be the minimum values given in the material specifications for the grade and heat treatment of the material supplied. A plot of the stress-strain curve shall be supplied for each
material and grade of material. Reference information, such as drawing number shall be included to indicate the source of all area property information.

The preliminary and final submittals shall be submitted in paper and electronic form. The Contractor shall provide Drawing engineers with access to the FEM at the Contractor’s site at both the U.S. and European facilities.

Upon final completion of the final design, the FEM model shall be updated to represent the final configuration of the structure.

The element mesh cannot be fully approved until after analysis results are submitted for review, since mesh adequacy and accuracy are determined by the analysis results. Excessively distorted, warped, or otherwise misshaped elements, which generate warning or error messages during the FEA runs shall be permitted only if all of the following conditions are satisfied:

1. Re-meshing efforts to eliminate these elements are exhausted.
2. Contractor successfully demonstrates to Drawing that any residual misshaped elements are not located in critical regions or located in high stress gradient regions.
3. The overall results shall not be adversely affected.

### 3.6.6 Stress Analysis Report

The stress analysis report shall conform to APTA C&S-034-99 Section 7.3 and include the finite element analysis and manual calculations. In addition to the APTA requirements, the report shall include:

1. References for all formulas, calculation procedures, buckling coefficients, material strengths, and like items cited where these items appear in the stress analysis.
2. A tabulation of the Contractor's selection of allowable fatigue stresses and assumed applied fatigue stress ranges for structural members which are critical in fatigue.
3. If spot welds are used, table(s) showing the minimum strength and fatigue strength of single and multiple spot welds shall be given. Values shall be given for each material, temper, weld size, and thickness.

If the contractor conducts tests to provide necessary data, the entire test report shall be submitted. This report shall show as a minimum, the test procedure, raw and reduced data, and summary.

### 3.6.6.1 Finite Element Analysis Report (FEA)

The Finite Element Analysis Report including a paper and electronic portion is required for review and approval. For each load case under consideration, the paper report shall contain element plots that portray the applied loads, boundary conditions, coupled degrees of freedom,
constraint equations, static equilibrium, and all other special conditions of the load case. Similar type plots shall be furnished which show the assignments of the element properties (real constants), and the material properties. Auxiliary plots shall be provided, as needed, to clearly display all the elements. All plots shall contain a title clearly describing the plot contents, and include the coordinate axes triad. A legend and key, explaining all symbols, nomenclature, and colors used in the plots, shall be included in the report.

The paper report shall contain deflection (displacement) plots for each load case. There shall be separate plots for each component (x, y, and z) of deflection, as well as an overall total deflection plot. The displacement plots shall be of the color-contour type that shows the displaced and un-displaced configurations. Multiple views shall be provided as necessary to illustrate the deflections in all portions of the model, including any internal members that normally are not seen in typical hidden view plots.

The paper report shall contain stress plots for each load case examined. The report shall contain, at a minimum: maximum and minimum principal stress color contour plots; maximum and minimum principal stress vector plots showing the direction of the respective principal stress; and Von Mises equivalent stress (or other approved and agreed-upon combination stress) color contour plots. If shell elements are present in the model, stress plots shall be provided for the top and bottom surfaces. A legend describing the values associated with the color contours and all symbols shall be included in the report. Multiple views shall be provided as necessary to display the stresses in all portions of the model, including all internal members.

All plots shall show the maximum and minimum values and all values that are greater than 80% of the specified maximum value, and include a triad showing the direction of the global axes. Plots at high magnification shall be keyed to a plot showing the structure to an extent sufficient to orient the high magnification plots. There shall be a sufficient number of plots for each load case to see the stresses in all areas of the carbody. All areas within a Margin of Safety (MS) less than 0.2 shall be shown in detail.

At the discretion of Drawing, the finite element models and results shall be reviewed during live interactive sessions three weeks after each submittal. At these sessions, Drawing 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 Drawing’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 to view post-processed results.

The Contractor shall verify the sufficiency of the mesh density by comparing the nodal (averaged) stress results to the element (un-averaged) stress results. If the two stress results differ by more than 5% or other agreed value, the mesh of the global model shall be refined in the affected region, or alternately, a detailed sub-model of the region shall be generated and analyzed. In addition, the Contractor shall provide agreed-upon FEA software-generated error estimation distribution plots for the model and sub-model. Strain energy plots for the model and sub-models shall also be furnished.

For all linear-elastic load cases, the elastic stability of plates, webs, and flanges shall be calculated for members subject to compression and shear greater than 35% of the material yield.
strength. The variation of compression modulus with stress in stainless steel shall be considered in calculating compressive stability of stainless steel members. Locations where the Margin of Safety (MS) is less than 0.20 shall be shown in a table along with the design loads which cause the stress.

The element mesh, all assumptions, and all input data, such as loads, boundary conditions, coupled degrees of freedom, restraint equations, area properties, validations, strain gauge correlations as gained from load cases measured on the railroad and material properties shall be included as part of the model submittal and again as part of the complete analysis.

The preliminary and final submittals shall be submitted in paper and electronic form. The Contractor shall provide Drawing engineers with access to the FEA at the Contractor’s site at both the U.S. and European facilities.

Upon completion of the final design, the FEA analysis report shall be updated to represent the final configuration of the structure.

### 3.6.6.2 Manual Linear-Elastic Stress Analysis

The purpose of the manual analysis is to examine details of the carbody structure (weld connections, welded and/or bolted joints, fatigue conditions, column and plate stability) that are not readily evaluated in the FEA. The conventional analysis format consists of a title, sketch of item to be analyzed with dimensions and applied forces, drawing reference, material properties, allowable stress, detailed stress analyses and conclusions. Forces and moments for the analyses of each connection can be obtained from the FEA. A manual stress analysis of the following specific items is required:

1. The attachment of the coupler draft gear to the underframe;
2. The connection of the trucks to the frame, including calculated vertical and horizontal capacities;
3. The following critical joints for design loads in **TS 3.5**:
   - Collision post to end sill, and to structural shelf,
   - Corner post to end underframe, to intervening structure, to roof rail,
   - Anti-climber and coupler support structure to end sill,
   - Bolster to side frame and posts,
   - Lower corner of door frame,
   - Upper corner of door frame,
   - Critical cross-bearer to side sill and to center sill,
• Critical floor beam to side sill and to center sill,
• Critical side frame post to side sill,
• Critical side frame to underframe for 40,000 pound side load,
• Joints that cannot be adequately analyzed by the FEA

In computing the shear strength of a beam (or post) only that portion which is in line with the force vector shall be considered as resisting the force. If the force is skew to the web, the force vector shall be divided into components, one in line with the web and the other in line with the flange and the shear resistance shall be computed separately for each component.

Locations where the Margin of Safety is less than 0.20 shall be shown in a table along with the loads which cause the stress.

3.6.6.3 Elastic-Plastic-Buckling Analysis

The progressive buckling of controlled-crush zones designed in accordance with TS 3.5.2 and APTA SS-C&S-034-99, Rev 2, Section 7.4 shall be analyzed using an approved elastic-plastic-buckling computer model (FEA explicit code) such as LS-DYNA, PAM-CRASH, or ABAQUS/EXPLICIT. Approval of the analysis shall be based, in part, on the clarity of the pre- and post-processing graphical interface and the extent to which the accuracy of the program has been verified by previous comparisons of analytical results with test results. The analysis shall demonstrate that the requirements of TS 3.5.2, and TS 3.5.8 as appropriate, have been met.

3.6.7 Comparison of Analysis with Test Results

In order to verify the accuracy of the stress analysis, stresses measured during the carbody structural tests shall be compared to the results of the stress analysis for the vertical and end compression load cases. Strain gauges selected for the purpose of the comparison shall be representative of the primary vertical and longitudinal deflections of the carbody in response to the applied loads. Gauges on the top and bottom chords of the side frames, underframe sills, roof purlins, major side and end frame posts, body bolsters, and representative locations on side frame, roof sheathing, and under floor shear panels shall be included. The selected gauges shall consist of an array around the perimeter of the body at several representative cross sections along the length of the body, including but not limited to one with window openings, one with door openings, and one without either opening. There shall be a minimum of 50 gauges selected, which shall be identified on the strain gauge diagram included with the test procedure for Drawing review and approval.

A table with all stress output data from the strain gauges, the calculated values at corresponding locations, the deviation (absolute value and percentage difference of the measured stress), as well as the utilization shall be provided.

The percentage difference shall be calculated as:
% Difference = \( \frac{(\text{Measured} - \text{Predicted})}{\text{Measured}} \times 100 \)

The stress utilization shall be calculated as:

\[ \% \text{Utilization} = \frac{(\text{Measured})}{(\text{Allowable})} \times 100 \]

It may be appropriate to exclude certain strain gauges from the comparison made between test measurements and analysis predictions. The following filter methods may be applied to the strain results to exclude gauges from those used in comparison:

- Measured stresses with a utilization of less than 0.25 are considered as insignificant from a structural point of view. The corresponding deviations are not further evaluated.
- Deviations less than the accuracy of the measurement are not further evaluated.
- If measured stress values lower than predicted are due to conservative assumptions in the finite element model, the corresponding deviations are not further interpreted.

The rationale for exclusion of particular gauges from the validation exercise shall be stated and explained.

The results predicted by the stress analysis and the measurements made during the test shall be compared to one another. Successful model validation requires that:

- Any deviation between the measured deformations and the calculated deformations shall be within a range of +/-10%.
- Any deviation between the measured stresses and the calculated stresses shall be within a range of +/- 20% for at least 80% of the strain gauges evaluated, after applying any of the filtering methods described above.
- Any deviations in the stress comparisons between measurement and calculation larger than +/-20% shall be commented and explained.

Significant positive deviations between test and analysis (measured stress higher than predicted value) shall be thoroughly investigated; the cause shall be identified and the consequences on the structure shall be evaluated and documented. Additionally, any locations that indicate deviations between measured stress and predicted value in excess of the acceptable criteria require further investigation and explanation. Significant deviations between the stress analysis and test results may require refinement of the stress analysis in order to more accurately reflect the conditions of the tested structure. Alternatively, a detailed explanation, including supporting manual or finite element analysis, of the reasons for the excessive variance shall be included in the carbody test report.
3.7 SAFETY APPLIANCES

Safety appliances shall comply with the applicable requirements of the 49 CFR 231. Locomotives shall be equipped with recessed handholds and side door steps in accordance with 49 CFR 231.14. Side door steps shall have a serrated tread surface. The Contractor shall be responsible for advising Drawing of areas where existing FRA safety-appliance requirements may not be applicable and where waivers may be necessary because of the uniqueness of the design or operation of the locomotives.

3.8 SANDBOXES

A total of four sandboxes (two at each end) shall be provided on each locomotive. Each sandbox shall have a capacity of at least four (4) cubic feet and shall be located to minimize the length of sand piping. Boxes shall be constructed of stainless steel and fitted with watertight hatch covers for filling from outside and shall have suitable clean-out openings at the bottom. The angle of the sand box slope shall be greater than the angle of repose of the sand to ensure that the sand shall freely dispense sand to axles 1 or 4, depending upon direction of motion.

3.9 COUPLERS AND DRAFT GEARS

Couplers and draft gears shall meet the following requirements:

A. High strength steel, Type F, interlocking couplers, with associated operating mechanisms, coupler mountings, draft gears, yokes, coupler carriers, wear plates, bushings and shims, brackets, and coupler stops, shall be provided at both ends of each locomotive.

B. Coupler systems shall conform to the requirements of 49 CFR 229.141, 49 CFR 238.207 and applicable AAR standards and recommended practices

C. Coupler height shall be 34-1/2" +0"- 1/2" above top of rail to the centerline of the coupler, for a maximum empty locomotive

D. A MS488 6A or approved equal, draft gear and yoke shall be provided at each end.

E. An uncoupling device arranged to operate from either side of the locomotive shall be provided at each end.

3.10 MACHINE ROOM

Contractor shall provide a complete description of the machine room equipment layout to include the roof, underfloor and front end. A locomotive aisle, or aisles, from cab bulkhead to cab bulkhead, shall be sufficient to provide a safe passage for the crew and access for personnel to perform maintenance and module removal.

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4 INTERIOR FIXTURES AND APPOINTMENTS

4.1 INTERIOR FINISH - GENERAL REQUIREMENTS

4.1.1 General

The interior of the cab shall be free of sharp corners or edges to eliminate the possibility of injury to the passengers or the operating and maintenance personnel in either normal usage or emergencies. Performance criteria for energy absorbent material to be used in the passenger compartment shall be driven by the Crash Energy Management analysis.

All interior fixtures and seats in crew-occupied areas shall resist accelerations of 8g longitudinally, 4g vertically, and 4g laterally. This must comply with 49 CFR 238.

All interior surfaces, including cubicles, shall be painted with epoxy gloss white paint, except for cab that is detailed in Section 5.

4.2 INTERIOR SIDE LININGS AND CEILING

4.2.1 Interior Lining Installation

Interior linings shall be applied and mechanically fastened to their supporting surfaces. The mounting shall be designed to accommodate the dynamics of vehicle movement without transmitting stress to the linings. Interior linings shall be designed to have a minimum 1 inch radius cove at intersecting adjacent surfaces. Sharp, 90°, inside or outside corners shall not be allowed. All interior lining attachments shall be capable of resisting accelerations of 8g longitudinally, 4g vertically, and 4g laterally without damage.

"Anti-squeak" tape shall be used between all linings and any structure to which they are attached or with which they come in contact. Where linings cover apparatus requiring replacement, or even infrequent maintenance, they shall be equipped with lanyards and fastened with captive, machine screws, designed to allow ready access for removal and replacement of apparatus. Where necessary, access panels shall be hinged and secured with approved, locking, quarter turn fasteners.

The interior linings and moldings shall be free of all undulations. The maximum allowable variation from a designed contour on all interior surfaces shall be 1/8 inch over 3 feet in any direction.

Lighting fixtures shall be properly supported from the car body structure by secondary structural bracketry.
The design and layout of the interior linings shall minimize the size and number of the seams and moldings. Exposed fasteners shall not be allowed, unless specified or approved for a specific application and if so, they must be of stainless steel.

Cab interiors shall be designed for ease of cleaning. The floor wall junction shall have a coved profile included in the interior design enabling easy sweeping. Inside corners shall also have a radius cove or “heel plate” to hinder dirt collection and aid in sweeping. Where suitable, coving may be used.

4.2.1.1 Side Lining and Ceiling Materials

Materials currently in use by SEPTA or generally accepted in the rail industry that are based on low smoke and toxicity may be offered to SEPTA for consideration. All materials shall be approved by SEPTA as to the appropriateness for the application. Materials shall also be chosen for aesthetics, longevity, ease of cleaning, repair, replacement, and recyclability.

SEPTA will consider materials which it does not currently use or which are not in general use in the industry if these materials meet the requirements of Section 15. SEPTA encourages the use of innovative materials such as super plastic aluminum, honeycomb panels and other techniques in use in the aerospace industry.

4.3 INTERIOR PARTITIONS

Structural and privacy partition panels shall not use plymetal or plywood. Partition materials used between the cab and equipment areas, including doors, shall have acoustical reduction attributes to isolate operational noise in the cabs.

The color and finish of any partitions shall be subject to SEPTA approval at the cab mock-up design review.

4.4 CARBODY INSULATION

4.4.1 General

The floor, roof, sides, and ends of the carbody shall be thermally and acoustically insulated to the extent required to minimize heat loss and meet interior sound level requirements as specified in Section 2.1.1. The materials used for this purpose shall be at least as fire resistant as glass fiber insulation and shall have a maximum binder content of 6%. The insulation and all material used for vibration dampening shall meet the flammability and smoke emission requirements specified in Section 15.18.

4.4.2 Thermal

Insulation shall be used throughout the roof, floor, side walls, and ends of the locomotive bodies for thermal insulation where required in the cab.

A vapor barrier shall be provided between all interior linings and any frame mounted insulation.
Thermal breaks shall be provided at any location where it is necessary to interrupt an all-metal path between the interior and the outside of the structural skin.

### 4.4.3 Acoustical

A vibration and sound dampening material shall be applied to inner surfaces of all areas of the structural shell, including sub-floor pans, ends, roof, and side frames. The thickness of the dampening material shall have a vibration decay rate of not less than 35 decibels per second (at a temperature of 70°F) as measured by the Geiger thick-plate, SAE Standard J671, or other equivalent approved test method.

The damping material shall be a spray applied, water base, non-asphaltic, filled polymer in an emulsion form. Application shall be according to the supplier’s recommendations, and as follows:

The inner surface of the structural shell, except for the end and critical under-frame welds, shall be coated with sound deadening compound. The inside surfaces or structural members shall be sprayed to the maximum extent possible. The compound shall be applied wet to the supplier’s recommended thickness.

- Structural members under the floor of the carbody shall not be coated.
- The outside surfaces of the main air duct, the vertical underfloor equipment ventilation duct, and all ventilation ducts shall be coated with sound deadening compound. The compound shall be applied wet to the supplier's recommended thickness.
- Duct splitters (if used) shall be coated on one side only.

### 4.4.4 Floor Construction

The cab sub-floor panels shall be constructed of a minimum 21/32 inch overall thickness composite foam-core floor or an approved equal, which shall meet the requirements of Section 15.11.1. Overall thickness of the subfloor and covering, not including hardware attached to the panels, is not to exceed 1 inch. Floor material shall meet the requirements of 49 CFR 238.103 and shall have passed the ASTM E119-07 fire test. This shall be demonstrated in actual testing on a section of cab structure, in accordance with Section 15.18.3.

The panels shall be comprised of pieces optimized for ease of handling with transverse ship-lap joints located over structural members. There shall not be any longitudinal or transverse joints in the top or bottom face skins of the panel. The panels shall be installed on fully leveled surfaces. The panels shall be insulated from the metallic structure by an elastomeric tape with a thickness between 1/8 inch and 1/2 inch. Additional layers of tape may be used to level off the installation surfaces where supporting structural members may have overlapped. The width of tape applications must cover 80% of the supporting surfaces or more. All edges and penetrations through the panels must be framed and solidly sealed using a solid substrate material. Any attachments to the panel or through the panels must be into/through solid substrates designed into the panel for the purpose of the attachments. No attachments will be allowed into foam or honeycomb materials. All exposed edges of the panels,
including openings for ducts and conduits, and joints between panels, shall be waterproofed and sealed in an approved manner at the time the panels are installed.

The floor panels shall be attached to the floor structure using approved flat head fasteners. Alternative methods for attaching the floor panels shall be considered if the alternative method has a service proven history on locomotives. Reinforcements and steel tapping plates for any above-floor attachments shall be provided.

**4.4.5 Floor Coverings**

All floor covering color shall be approved by SEPTA.

Floor covering for the operating cabs shall have a cushioned sound absorbent top surface. The floor covering shall have an integral cove of liberal radius for easy cleaning, and shall extend from 2 inches to 6 inches up the wall. The joint between the wall lining and the cove shall be tight to prevent lodging of material which may cause odors.

The type of adhesive used to bond rubber or vinyl floor covering to the floor panels shall be that which is recommended by the manufacturer of the floor covering. Before applying the floor covering, all voids, fastener heads, and seams between floor panels shall be filled and the floor made smooth within 0.0625 inches over 3 feet in any direction with an approved leveling compound.

**4.5 DOORS**

**4.5.1 General**

A crew door is required between the machinery room and the engineer's operating cab in the locomotive. Outside entrance doors, are required on each side and at each end of the locomotive, within each operating cab. Crew doors, including the exterior and machine room doors, shall provide a minimum 23.5 inch clear passage. The exterior doors shall be lockable to prohibit unauthorized entry.

Locking mechanisms, operable with a standard SEPTA coach key from the exterior side of the exterior doors, shall be provided to secure the exterior doors in a closed position. Exterior doors shall be lockable and unlockable from the interior side of the cab without the use of a key.

**4.5.2 Construction**

**4.5.2.1 Exterior Crew Doors**

Side entrance doors may be constructed with face skins covering the base structure and with a honeycomb core or composite construction. Doors shall be of an adequate thickness for the intended service. The interior surface finish of the door shall match the interior finish of the surrounding panels. The door panels shall be vibration resistant and fully insulated against thermal and sound transmission. All door panel joints and edges shall be sealed against moisture. Drain holes shall be provided to permit
condensed moisture to escape. Reinforcements shall be provided at attachment points. All potential pinch points should be eliminated.

4.5.2.2 **Cab Bulkhead Doors (formerly Machine Room Doors)**

The crew door at the cab bulkhead shall be constructed from the same materials as the cab partition. The door shall be outwardly hinged for Engineer to egress from the cab into the machine room. A large push-type, "panic bar" handle shall be provided on the cab side of the door to facilitate rapid unlatching and exit. All potential pinch points should be eliminated.

4.5.2.3 **Door Panel Strength**

Exterior door panels shall withstand, when supported at both ends, a concentrated load of 200 lbs applied 90° to the plane of the panel at the center of the front face without deflecting more than 0.25 inches nor shall the panel take a permanent set. The concentrated load shall be applied over an area of four-by-four inches.

4.5.2.4 **Thresholds**

Thresholds at all door entrances shall incorporate an abrasive grit surface, and where required shall incorporate guides for sliding doors and drain holes to carry off water and accumulated debris to the outside. Thermostatically controlled threshold heaters shall be provided to eliminate the accumulation of snow and ice.

4.5.2.5 **Locks & Latches**

All locks shall be constructed of nickel bronze or stainless steel. Locks shall be keyed to the SEPTA standard coach key or shall be of a suitable mechanical construction for the purpose intended. A positive mechanical lock, operable with a standard coach key from either side of the door, shall be provided.

Pencil type locks are not permitted. Samples of all locks and latches shall be provided no later than 90 days after receipt of notice to proceed.

4.5.2.6 4.10 **Standard Keys**

SEPTA standard coach keys shall be used for normal locks other than other restricted access locks such as ATC/Cab Sig. and or propulsion control.

The SEPTA standard coach key shall be the J. L. Howard and Co. No. 2383 or approved equal.
4.6 SEATING

4.6.1 Seat Strength Requirements

The seat assembly shall meet the requirements of APTA PR-CS-S-011-99 and be designed to protect against injury, fatal or otherwise, to crew traveling in the seats when they are oriented in either forward or reverse direction. The seat pedestal and wall mount shall survive, without failure, a 8g longitudinal, 4g vertical and a 4g transverse load acting on the mass of the seating with 198 lbs. per seat load placement.

All seat frame structures shall be provided with seat belt points of attachment for the possible future installation of lap belt assemblies.

The seat body shall be designed and built to minimize injury to crew members under sudden stops and crash conditions. The basic premise shall be that the seat is expendable.

A dynamic crash test shall be performed using a Hybrid III test dummy to measure and record forces incurred during the crash test. The test shall be performed on a "High G" acceleration crash sled to the following requirements:

- 0 to 10g in 0.05 seconds
- 10g average for 0.125 seconds, with allowed oscillation of up to 2g superimposed.
- 10g to 0 in 0.05 seconds

4.7 WINDOWS

4.7.1 Glazing

All glazing shall meet the requirements of 49 CFR 223, 49 CFR 238 and ANSI Z26.1.

4.7.2 Windshield

Two FRA Type I windshields (one on each side of the body end door) of the same size shall be provided at each cab end of every car. They shall be located at the same height and shall be symmetrically positioned with respect to the longitudinal centerline of the car. Each windshield shall be a flat piece of nominal 0.5625 inch thickness triple-laminated high impact untinted glass. No curved surfaces are permitted.

The windshield dimensions shall permit a maximum field of view for a seated Operator. The design and installation of the windshield shall minimize external glare as well as reflections from inside the car.
The windshield shall be electrically heated using 230 volts 60 Hertz AC single phase power. Heating control shall be as specified in Section 5.3.2. The electrical wiring connections shall be on the inside of the glazing, preferably at the top.

Windshields shall be laminated type, consisting of two or more pieces of tempered glass bonded with polyvinyl butyral resin interlayer arranged for defrosting by means of an electrically conductive coating.

The windshield shall not indicate a bow of more than 0.030 inch per linear foot. Corners and edges shall be ground smooth and all edges shall be sealed. Windshields containing delaminated areas are not acceptable. All windshields shall comply with FRA Regulations for Type I glazing (including installation) and shall be so marked.

### 4.7.3 Cab Side Windows and Door Windows

Cab side windows shall be a vertical sash panel (drop type). The clear opening shall be a minimum of 19.5 inches high by 18.5 inches wide and window shall be easily accessible by the Engineer from his seat. Any deviation from this size shall be subject to SEPTA approval. Locks and keepers shall not encroach into this opening.

The sash shall be designed to permit an Operator to easily lean out, when either seated or standing, and be able to view a station platform or the wayside in either direction. Each section of the sash shall have a flat piece of FRA Type I nominal 0.46 inch thickness tinted polycarbonate window glazing, installed in the frame with elastomer sections to form a watertight seal. No more than fifteen pounds of force shall be needed to initiate opening of the sash and no more than 10 pounds of force shall be needed to move the sash from any other point.

The standard key shall be required to initially unlock the sash, upon which it shall not require the use of the key to open if the sash was then closed. The sash can be key-locked closed when desired, such as when the Operator leaves the cab. The lock shall be of a highly durable design which is resistant to being picked or forced open.

The sash frame shall be constructed of extruded aluminum alloy of type 6061-T6 or T4. The entire sash design and installation shall be approved by the Engineer.

All cab side windows and door windows shall comply with FRA regulations for Type I glazing and shall be so marked.

### 4.8 SIGNAGE & DECALS

All signage shall be in accordance with SEPTA requirements. All graphics applied to the vehicle interior and exterior shall be constructed from an approved adhesive backed, vinyl film, applied and edge sealed, if required, in accordance with the manufacturer’s instructions. The location, size, text, color and application shall be approved by SEPTA. All graphics layouts shall be submitted for approval at the cab design review.

As a minimum, graphics shall be provided for the following:
• Four conceptual exterior color schemes, utilizing vinyl film decals arrangements, shall be designed by a professional Graphic Designer and presented to SEPTA for evaluation and selection. Exterior Locomotive Numbers shall be incorporated in the schemes.

• Locomotive Numbers, Interior - The locomotive number shall be applied to the inside both of the locomotive cabs in areas to be approved and in a sequence and style also to be selected by SEPTA.

• Contractor's Name Plate - Two permanent builder's plates shall be applied to the interior of each locomotive, one in each cab. Plate size, wording and location shall be approved by SEPTA. The ownership plate, if required and Contractor's name plate shall be stainless steel, with etched and painted lettering.

• All hidden devices shall have their location indicated with signage. Interior signs or those located in enclosed areas shall be either stainless steel or aluminum with etched and painted or engraved lettering. Lettering on aluminum signs may be photo etched as an alternate style of lettering. Signs located on the exterior of the locomotive must be stainless steel as described above.

• Other designations - Additional approved graphics shall be provided for safety information and cut-outs. All safety related decals shall meet the standards of APTA PR-PS-S-002-98, latest revision.

The sign listing above may not represent all the signage that is required. Additional signs shall be added in accordance with the other sections of this Specification and at the discretion of SEPTA.

4.9 HANDHOLDS and SUPPORTS

Handholds and supports shall comply fully with all 49 CFR 231 requirements including location, thickness, finger clearance, bracket supports, and locking fasteners. Handholds, supports and associated fasteners shall be constructed of stainless steel.

4.10 SAFETY EQUIPMENT

4.10.1 Fire Extinguisher

One carbon dioxide, or environmentally-suitable Halontron equivalent fluid, seventeen pound fire extinguisher, UL rated 2A-40 B:C, shall be provided in each cab and two additional extinguishers shall be located in the machine room, less than 40 inches above the floor. The fire extinguishers shall be clearly marked with instructions in accordance with NFPA Specification No. 10A.

The fire extinguishers shall be stamped in 0.5 inch high letters "Property of SEPTA". See also Section 5.12.5.
4.10.2 Emergency Tools

An 18-inch pinch bar and adjustable pipe wrench shall be provided and installed in a manner that shall prevent vibration and rattling and be readily available for emergency use. The emergency tool compartment shall be conveniently located and shall be subject to SEPTA review.

4.10.3 First Aid Kit

A ten unit First Aid Kit, equivalent to Eveready p/n AM1202 or Coyne p/n 10PA shall be provided and stored inside the Emergency Tool Locker in each cab.

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5 OPERATING CAB

5.1 GENERAL

An operating cab shall be provided at each end of the locomotive. The operating cab shall be of full width design. The interior of the cab shall present a clean, pleasing appearance, be arranged and finished to minimize injury to an Operator in the event of an accident or collision, and shall be free of sharp edges, protruding objects, safety hazards and floor obstructions as required by Military Standard MIL-STD-1472, latest revision. The arrangement and equipment of all cabs shall be identical.

The cab shall be designed in such a manner that all devices and equipment are integrated (built-in and flush-mounted) into the console, walls, ceiling or floors to give the appearance of a single entity. The design shall group controls and instruments for function, maintenance, and clean-ability. All hardware shall be attached with machine screws to either tapping plates or captive nuts. All interior fixtures and seats in crew-occupied areas shall resist accelerations of 8g longitudinally, 4g vertically, and 4g laterally. This must comply with 49 CFR 238.

The cab equipment layout and console configuration shall be designed to accommodate Operating Engineers from the 5th percentile female to the 95th percentile male ranges. Seating placement shall consider the Engineer's relationship to the console and the windshield. The relationship between the Engineer and the windshield shall be designed to optimize the viewing area while minimizing the windshield area. The Engineer's minimum clear viewing distance from the seated position shall be no more than 40 feet to the top of rail and no more than 40 feet to catenary at a point 18 feet above top of rail. The cab layout shall also be arranged so as to provide the Engineer with an effective field of view to the right and left of the direction of travel. Obstructions to the field of view caused by required structural members shall be minimized.

Primary console operating features shall be positioned to be accessible and functional from the Engineer's optimal seating position with all required controls and display instrumentation mounted within the operating crew console desk. Normal operation shall not require awkward and unnatural positioning, extension or excessive motion on the part of the Engineer. Switches and controls on the Engineer’s console shall be kept to a minimum. Simple devices shall perform multiple tasks.

Secondary controls, switches and features not used in the performance of operation of the locomotive shall be placed in an enclosure away from the Engineer but easily accessible from the cab area. However, HVAC temperature control must be accessible from the engineer’s seat. The location of all secondary controls shall be subject to SEPTA approval. Electrical and control enclosures shall be designed to be water and dust resistant.

The crew door at the rear of each cab shall be as described in Section 4.
5.1.1 Cab Construction

Requirements for the cab construction are as follows:

- Structure is described in Section 3;
- Interior lining, floor, door and windows are described in Section 4 and 5;
- HVAC is described in Sections 5.4 and 7.6;
- Lighting is described in Section 7;

5.2 CAB EQUIPMENT

Each cab shall be fitted with all necessary appointments, indicators and controls, including but not limited to, the following integrated items or devices:

5.2.1 Cab Appointments

The following appointments shall be provided in the cab:

- Two Engineer seats (Section 5.7);
- Control Console (Section 5.3);
- Heated windshield (Section 5.5 and Section 6);
- Roll down tinted sun shields (Section 5.12.2);
- Tinted side glass, (Section 5.5);
- MAP form holder;
- Holder for FRA Inspection Form FRA F 6180-49A;
- Built-in gimbaled cup holders (one per seat);
- Built-in trash container with disposable trash bag liner (Section 5.12.3);
- Refrigerator (Section 5.12.4);
- Rear view mirror, and rear view cameras, each position; and
- 120 VAC and 74VDC receptacle;
5.2.2 Cab Area Appointments

The following appointments shall be provided in the cab or in close proximity to the cab:

- Convenient storage for hanging bag and Engineer's grip bag;
- One fire extinguisher (Section 5.12.5);
- One first aid kit (Section 4.10.3);
- Flare container;
- Data port;
- Access to event recorder download capability; and
- Tool box and tools in machine room.

5.3 CAB CONSOLE

5.3.1 General

An Operating Engineer's console shall be provided in each cab. The console shall include all necessary operational elements and indicators, such as switches, indicators, the communications control panel, control transfer switch, reverser switch, master controller, alerter whisker, and both audible and visual performance warning indicators. The console shall be a panoramic configuration and shall be a light color, subject to SEPTA approval.

The display panel shall be shaded against direct sunlight and positioned at 90 degrees to the Operating Engineer's line of sight. The console shall be compatible with the range of adults from a 5th percentile female to a 95th percentile male. All operating controls shall be placed in normal reach of the Engineer in the seated position.

Upon approval of a layout, the Contractor shall incorporate the approved design as part of the cab mock-up.

The cab console shall be illuminated for daytime and nighttime operation without causing any reflections or glare on the windshield. The Contractor shall provide appropriate shielding around the console to reduce sun glare and prevent wash out of console displays. The console light shall be controlled by a dimmer switch as described in Section 5.6. The console light shall be located on the console and shall properly illuminate all switches and gauges necessary for operation.

All controls and indicators located in the Engineer's cab as required by the Specification shall be arranged in a logical and orderly manner with speedometer and cab signal aspect display unit centered. All indicators shall be positioned to be in the line-of-sight of the Engineer when in the normal seated
position. Controls shall be located such that they are conveniently reached, based on their importance or frequency of use.

Controls or indicators that are associated with a particular side of the locomotive shall be positioned on the associated side of the console or indicator panel.

### 5.3.2 Controls

The Engineer’s side of the console shall include all controls necessary for operation of the Train including, but not limited to:

- Visual Display Screens (two) (Section 14);

- Speedometer;

- Cab signal display, including provision for civil speed indication (Section 12);

- Master Controller, (Section 9) including:
  - Cab Actuation Control;
  - Reverser (with removable handle);
  - Throttle Handle;

- Brake Control Handle (Section 9 and Section 11);

- Radio control head with hand set (Section 13);

- Handset connector and hang-up cup (Section 13)

- PA/Intercom (Section 13);

- Headphone and speaker jacks (Section 13);

- Form D Holder (three spring clips) (Section 5.3.4.1);

- Power Meter (Head end power shall have an onboard power meter which shall display 480 VAC auxiliary power and trainline. The display shall give total voltage, current and frequency. There shall also be a power meter display for monitoring only HEP trainline output. The power meter display may be integrated into the cab display features.)

- All necessary indicators not otherwise included in the Visual Display Screens or Cab Signal displays.

- All necessary controls including, but not limited to, the controls indicated below:
<table>
<thead>
<tr>
<th>Switch Function</th>
<th>Switch Identification</th>
<th>Switch Positions/Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acknowledge</td>
<td>Acknowledge</td>
<td>Whisker (3-position momentary as described in Section 12)</td>
</tr>
<tr>
<td>Parking Brake Reset</td>
<td>Parking Brake - On/Off Reset</td>
<td>Maintained 2-position momentary switch</td>
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<tr>
<td>Non-Cab Territory</td>
<td>Non-Cab Territory</td>
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<td>Cab Signal/PTC Departure Test</td>
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<td>Trainline Pantograph Up</td>
<td>Pantograph Up</td>
<td>Momentary push button switch</td>
</tr>
<tr>
<td>Local Pantograph Down</td>
<td>Local Pantograph Down</td>
<td>2 position switch Normal/Down</td>
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<td>Trainline Pantograph Down</td>
<td>Pantograph Down</td>
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<td>Fire Acknowledgment</td>
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<tr>
<td>Marker Light</td>
<td>Marker Light – On/Off</td>
<td>Two Position</td>
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<td>Timetable Light</td>
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<td>Two position</td>
</tr>
<tr>
<td>Emergency Brake Application Light</td>
<td>Emergency Brake Application Light Reset</td>
<td>Momentary switch</td>
</tr>
<tr>
<td>Instrument Light Dimmer</td>
<td>Console Dimmer</td>
<td>Continuously variable</td>
</tr>
<tr>
<td>Cab HVAC Controls</td>
<td>Cab HVAC</td>
<td>As required</td>
</tr>
<tr>
<td>Horn control</td>
<td>Console</td>
<td>Horn valve</td>
</tr>
<tr>
<td>Dynamic Brake Cut Out</td>
<td>Regenerative Brake Cut Out</td>
<td>Two position</td>
</tr>
</tbody>
</table>

The following foot-operated controls shall be conveniently placed beneath the Engineer’s side of the console, arranged so that they remain conveniently accessible in all positions of the foot rest:

- Foot pedal, radio key (Section 13);

The Assistant’s side of the console shall include the following:

- Visual Display Screen (Section 14);
- Speedometer;
- Cab signal display including provision for civil speed indication (Section 12) (Alternatively, one cab signal may be display if visible to all members occupying the cab.)

The following controls shall be accessible from both the Engineer's and Assistant’s seats, either by placing the controls where they can be conveniently reached from either seat, or by providing duplicate controls:

<table>
<thead>
<tr>
<th>Switch Function</th>
<th>Switch Identification</th>
<th>Switch Positions/Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emergency Brake valve</td>
<td>EBV</td>
<td>Lever</td>
</tr>
<tr>
<td>Bell Control</td>
<td>Bell</td>
<td>2-position momentary switch</td>
</tr>
<tr>
<td>Sand Control</td>
<td>Sand</td>
<td>Momentary</td>
</tr>
<tr>
<td>Heated Windshield</td>
<td>Windshield/Heat - On/Off</td>
<td>Maintained</td>
</tr>
</tbody>
</table>
### Defroster

<table>
<thead>
<tr>
<th>Wiper Control (Section 5.12.1)</th>
<th>Traction /Door Interlock Bypass</th>
</tr>
</thead>
<tbody>
<tr>
<td>Defroster</td>
<td>Defrost - On/Off</td>
</tr>
<tr>
<td>Maintained</td>
<td>Wipers</td>
</tr>
<tr>
<td></td>
<td>Traction /Door Interlock Bypass</td>
</tr>
<tr>
<td></td>
<td>Two position sealed switch</td>
</tr>
</tbody>
</table>

All required audible alarms and signals shall be provided in the cab, located so as to be clearly audible to the Engineer and Assistant, and be readily accessible for maintenance. Audible signals requiring different actions shall have different sounds. Audible signals shall be no louder than necessary to be clearly audible in the cab under worst case conditions such as passing another train in a tunnel. The final levels shall be determined during acceptance testing. The audible alarms and signals shall include, but not be limited to:

- Cab Signal Audible Alarm;
- PTC Audible Alarm;
- Alerter Audible Alarm;
- Fault Alarm; and
- Conductor Signal Buzzer.

### 5.3.3 Control Components

All switches, controls, buttons and indicators used on the control console shall be rugged, high-quality devices, readily available from commercial sources. The minimum number of different types of device shall be used, and individual functional designations shall not be marked on the device. Designations shall be attached to or part of the console. All device types shall be subject to SEPTA approval.

Switches and controls shall be designed to prevent inadvertent action. Slide switches shall be used wherever possible unless otherwise approved. Any push button used may be flush mounted, raised or a mushroom-type design. Switch guards shall be applied where requested.

All controls and indicators shall be identified by engravings in the console panel. Multi-position controls shall have all positions identified. Adhesive-bonded tags shall not be permitted.

Safety controls, cut-out switches, cut-out cocks and similar devices which are normally sealed against manual operation shall be sealed with a “ROTO-SEAL” device, as manufactured by the E.J. Brooks Co. (164 North 13th St., Newark, NJ 07107). The following part shall be used: 8-inch wire seal - #45-240-00020.

### 5.3.4 Console Cabinet Construction

The control console and display panels shall be user friendly, easily removable for replacement, with maintenance and operation a major consideration. The display console shall be perpendicular to the Engineer's line of sight and any corresponding desk surface shall be at least 15 degrees from horizontal.
The control console shall be designed so that liquid spilled on the surface shall not damage or interfere with operation of components or back-panel wiring, and shall have a finish that can be cleaned with a soap solution in water.

The control and display panels shall be hinged and accessible to all controls, switches and indicators for routine maintenance. The panels shall be capable of being supported in the raised or open position. The majority of the console surfaces shall be a sound absorbent material. All fasteners shall be hidden from view unless approved by SEPTA. Aluminum components shall be permitted in the interior of the cab.

The console operating face shall be hooded to block direct sunlight and shall be constructed of a corrosion-resistant, integrally colored, non-glare material. The console cabinet shall be constructed of aluminum, to match adjacent cab lining materials.

All controls shall mount to hinged panels fastened to the console cabinet. Controls shall not mount directly to the console cabinet material. All control mounting panels shall be fastened to the console cabinet with approved threaded fasteners on permanently mounted spacers. An approved alternate method may be used.

The console shall be designed and shaped in such a manner to permit the Operating Engineer to open and lean out of the cab side windows to inspect the train. The console desk surface shall be easily removable for replacement.

### 5.3.4.1 Form D Holder

The console shall be equipped with a Form D holder. It shall accommodate a document of 11 inches by 11 inches, and shall be provided with three independent spring-loaded securement fingers at the top.

### 5.4 CLIMATE CONTROL

Each cab shall be provided with a quiet and efficient, forced-air HVAC unit mounted on roof or under the operator console. The Contractor shall provide full climate control with supply air delivered through individually fully adjustable diffusers for the engineer and assistant engineer seat locations. Complete HVAC performance requirements are described in Section 6.0.

No heat generating equipment shall exhaust air into the interior of the cab. Hot surfaces shall be insulated from direct contact with cab air.

### 5.5 CAB GLAZING

All glass used in the construction of cab windows shall be laminated safety glass meeting the requirements of Section 15 and Section 4. With the exception of the exterior crew door, all window material shall be FRA Type I material. The windshield shall be heated and incorporate a spall shield which shall be factory laminated to the inner surface of the glass panel.

The Engineer's side windows on each side of each cab shall be one piece, and shall be a plug design. The window shall be easily replaceable. The sliding plug window shall have wedge-type latches so that it
shall be air and water-tight when closed. The windows shall be effectively weather stripped, reinforced for hard usage and designed to eliminate rattles. The sash shall be so constructed that water drainage shall be to the outside of the car. Windows shall be easily replaceable.

The sliding sash shall be designed to slide freely in either direction. The sash design shall allow the sliding portion to maintain any desired opening during normal operating conditions; it shall also permit a crew member to lean out of the window and view the station platform in either direction.

5.6  INTERIOR LIGHTING

Each cab shall be provided with two ceiling lights that shall be part of the emergency lighting circuit. The fixture shall be suitably placed in the ceiling to illuminate the Engineer's console and the general cab area. The light beam shall be controlled to avoid glare on the windshield. The illumination intensity measured on the Engineer's controls shall be 20 foot-candles and 15 foot candles at the floor (Section 7).

The cab ceiling light shall be controlled from a two-position switch on the Engineer's console and from outside controls at the foot of the cab door steps as described in Section 7.

The console lighting shall be part of the Low Voltage Distribution Network. A dimmer control shall be provided for variable adjustment of the brightness.

A timetable light on the console shall be provided. The light shall be installed in a flush-mounted, durable fixture which shall protect against damage and lamp breakage.

A light, on a ten minute timer circuit, shall be provided in the storage room.

The complete cab lighting arrangement shall be included and reviewed in the cab mock-up.

5.7  CAB SEATING

Each cab area shall be equipped with three (3) seats; two (2) matching long-distance Engineer's seats, and one flip-up seat for the Supervisor. The seats shall be located in such a manner as not to obstruct normal train operation or emergency egress. The seat pedestal and wall mount shall survive, without failure, in a 12g longitudinal, 4g vertical and a 4g transverse load acting on the mass of the seating with 185 lbs. per seat placement. All seat frame structures shall be provided with seat belt points of attachment for the possible future installation of lap belt assemblies.

The Engineer's seats shall be placed facing forward optimally as close and high to the windshield as permissible to maximize track visibility and overall forward view.

Adjustable foot rest platforms shall be provided in front of the operators. The seat shall easily rotate 180° to allow emergency use of the seat which shall lock in reverse to provide the maximum secure position. SEPTA shall review and approve the design and locations of these seats.

The Supervisor's flip-up or folding seat shall be located at the center or the right side of the cab on the transverse bulkhead or in another location as approved by the Engineer. The seat shall be a single...
occupant, spring-loaded theater type design that shall fold up out of the way when not in use. The seat shall lock in both the folded and seated positions. Protruding legs or support brackets shall not be acceptable.

The individual features for all seats shall be of the highest quality and shall function as intended. The operation of seat features and functions shall be capable of being performed easily and conveniently from the seated position to avoid unnecessary Engineer distraction. Movement, rotation, and articulation of seat components shall be free of binding, unnecessary friction, and wobble. The seat shall not have inherent pinch points in the design.

The design of the seats shall consider maintenance accessibility. All seat components shall be mechanically fastened and serviced with common hand tools.

The Engineer's seats shall be a SEPTA approved seat, modified as necessary to meet the requirements of the first paragraph of this Section. The Engineer's seat shall have the following features:

- Recline;
- Folding armrests, with a vertical fold away feature;
- Adjustable height;
- Bottom cushion spring assembly;
- Cloth upholstery easily removable via a “hook and loop” arrangement;
- Full back pan protection for the fabric and edges;
- Manually adjustable from seated position;
- Lumbar support.
- Cloth upholstery which meets the requirements of Section 15;
- Cushion bottom and back shall be removable without special tools;
- Cushion bottom shall be a spring construction with minimal foam cushioning;
- Cushion bottom shall lock in both the seated and stowed positions.

The Engineer's seats and attachments shall comply with the requirements of 49 CFR Part 238.233. In addition, the seat shall comply with the requirements of APTA standard SS-C&S- 011-98, Standard for Cab Crew Seating Design and Performance. All seat assemblies shall meet the smoke and flammability requirements of Section 15.
5.8  DOOR CONTROL AND SIGNAL SYSTEM

5.8.1  General

Provision is required for a door closed signal trainline function with the capability to inhibit train movement until all exterior passenger side doors are fully closed and locked.

The doors closed signal shall be considered to be a safety critical function, when the locomotive is in consist with non-equipped passenger cars this function shall be inhibited.

5.8.2  Passenger Side Door Interface

5.8.2.1  Trainline Signal and Traction Interlock

A trainline function shall be provided with an indication in the activated cab when all exterior passenger side doors in the train are closed and locked. This function shall be generated within the passenger car or train monitor system when fitted. The function is safety critical. It shall be used to inhibit train movement until all passenger doors are closed and locked.

A sealed by-pass switch shall be provided in each operating cab to by-pass this traction interlock function and permit the train to be moved in the event of a failure. The by-pass condition shall be recorded by the LDMS.

5.9  CAB INTERIOR SOUND LEVELS

Cab noise levels for a stationary (static) locomotive and for a moving (dynamic) locomotive shall be based on normal operating conditions, defines as all speeds up to 135 mph under load at full throttle with all doors and windows closed and with all motorized equipment in the cab operating.

5.9.1.1  Stationary Noise Levels

Cab noise level shall be subject to 49 CFR 229.121, paragraphs (a)(1) and (a)(3), except that the noise level shall average less than or equal to 75 dBA with an upper 99% confidence limit of 77 dBA. Compliance of the interior cab static sound levels with this requirement shall be verified following the protocols found in 49 CFR 229 Appendix H, Static Noise Test Protocols – In-Cab Static. In as much as the locomotive is electrically powered, the reference(s) to “engine speed” should be replaced with “operating air compressor and equipment cooling apparatus”.

5.9.1.2  Dynamic Noise Levels

Cab noise level shall be subject to 49 CFR 227, except that the allowable noise levels shall be lower. Exposure to continuous cab noise under normal operating conditions shall not exceed a twelve-hour, time-weighted average of 76 dBA. Exposure to continuous cab noise shall not exceed 85 dBA with normal operation of the bell and the horn at maximum volume included.
Continuous noise is any sound with a rise time of more than 35 milliseconds to peak intensity and a duration of more than 500 milliseconds to the time when the level is 20 dB below the peak.

When the continuous noise exposure is composed of two or more periods of noise exposure of different levels, their combined effect shall be considered. Exposure to different levels for various periods of time shall be computed according to the following formula:

\[ D = \frac{T_1}{L_1} + \frac{T_2}{L_2} + \ldots \frac{T_n}{L_n} \]

where:
- \( D \) = noise dose
- \( T \) = the duration of exposure (in hours) at a given continuous noise level
- \( L \) = the limit (in hours) for the level present during the time \( T \) (from the table below)

If the value of \( D \) exceeds "1", the noise exposure exceeds permissible levels.

<table>
<thead>
<tr>
<th>Sound Duration Permitted (hours)</th>
<th>Level (dBA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>76</td>
</tr>
<tr>
<td>8</td>
<td>79</td>
</tr>
<tr>
<td>6</td>
<td>81</td>
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<td>4</td>
<td>84</td>
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<td>2</td>
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<tr>
<td>1.5</td>
<td>91</td>
</tr>
<tr>
<td>1</td>
<td>94</td>
</tr>
<tr>
<td>0.50</td>
<td>99</td>
</tr>
<tr>
<td>0.25 or less</td>
<td>104</td>
</tr>
</tbody>
</table>

Compliance of the interior cab dynamic sound levels with these requirements shall be verified using the microphone locations stipulated in 49 CFR 229 Appendix H, Static Noise Test Protocols – In-Cab Static. The microphone location for the right-hand operator’s seat shall be relocated to another close proximity location since the seat will be occupied during the test.

Subjective observations by the operator during the testing should be documented, particularly where comparisons with other locomotive equipment might be made.

### 5.10 VIBRATIONAL NOISE

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 0.03in/s peak for frequencies above 20 Hz.
All equipment installed in the cab shall be designed to reduce or eliminate vibration and noise transmission. The operating cab shall incorporate sound and vibration engineering techniques, proper dampening, and/or gaskets, to prevent rattling and vibrational noise.

Components that cause noise, vibration, or oil canning shall not be acceptable. All cab components shall be evaluated individually for their noise contribution such as windows, cab seats, doors, lighting fixtures, and hardware. If noise from vibration is caused by any part of the vehicle equipment, the Contractor shall modify and revise the design to eliminate this condition.

### 5.11 NOISE EMISSIONS

The Contractor shall use the appropriate construction materials for attenuation and abatement of noise emissions. Insulating materials or coatings shall meet federal guidelines for protection against fire and shall be non-toxic if exposed to extreme heat. Confined materials shall be non-hygroscopic and of a type which does not settle or lose noise attenuation properties with service life.

Cab roof and side walls shall be fully sound insulated. Air ducts shall be baffled as required to control wind noises and to attenuate exterior noises.

Refer to Section 2 for external noise emission requirements.

### 5.12 MISCELLANEOUS EQUIPMENT

#### 5.12.1 Windshield Wipers/Washers

Windshield wipers shall be provided for each windshield. The wiper and washer controls shall be convenient and accessible from both Engineers’ seats. 100% of the Engineer’s core field of view, as defined in Section 5.1, projected to the windshield area shall be swept over a complete cycle. The windshield wipers shall be functional at all vehicle speeds.

The drive units shall provide two speeds of synchronized operation and shall return the wiper blades to a PARK position at extreme ends of their sweep in the OFF position. The PARK position shall be at the inboard or outboard edges of the windshield. There shall also be an adjustable intermittent, 3 to 30 second delayed mode of operation. Drive units shall be electrically operated, and use brushless motors. The wiper mechanism shall operate smoothly without hesitation throughout its cycle under all conditions. Wiper operating mechanisms and drive units shall be accessible for repair and replacement. The operating mechanisms shall be enclosed. The wipers shall be mounted at the bottom of the windshield glass. The wiper control switch shall be located on the cab console. The windshield wiper assembly shall be accessible and replaceable from inside the cab.

A windshield washer shall be supplied for each cab. The spray head shall uniformly distribute the fluid over the windshield and shall be mounted on the carbody. A translucent reservoir with a 5-gallon capacity, minimum, shall be provided. The reservoir shall be located so as to permit filling from outside the vehicle. The reservoir shall be located inside the cab where fluid levels can be conveniently accessed.
and visibly monitored by the Engineer. The access cover shall be gasketed to prevent leaks into the vehicle. The location of the reservoir and fill system shall be approved at the cab mock-up.

## 5.12.2 Sun Shields

An adjustable roll-down opaque sun shield shall be provided in each cab for each exterior window such that the Engineer can limit sunlight coming through all windshields and both side windows. The sun shield shall be positional over the full height of the windows. Vibration and normal vehicle motions shall not cause the shields adjusted position to change.

## 5.12.3 Waste Receptacle

A detachable, waste receptacle, of approximately seven and one half gallon capacity, shall be provided in each cab within reach of the Engineer when seated. The waste receptacle shall be designed to be leak-proof, and shall be secured to its mounting surface to prevent rattling. The waste receptacle shall be designed to accommodate commercially available American trash bags.

## 5.12.4 Refrigerator

A minimum 0.35 cubic foot refrigerator shall be provided in each cab area for food storage. The refrigerator shall be recessed into a wall or locker to insure a clean unobstructed cab area. The ice shall be segregated from the food storage area.

## 5.12.5 Fire Extinguisher

One fire extinguisher shall be provided in each cab; one fire extinguisher shall be provided at each end of the machinery room. The extinguishers shall be as specified in Section 5.12.5. Each extinguisher shall be secured with an appropriate corresponding, heavy-duty retaining bracket with an over-center latch for securement, and shall resist accelerations of 8g longitudinally, 4g vertically, and 4g laterally. The extinguisher assembly shall be recessed into a panel to insure a clean, unobstructed cab area.

## 5.12.6 Warning Devices

Warning devices consisting of a bell and horn shall be provided at each cab. Control of each shall be by separate, momentary contact switches located on the cab console. Actuation of these warning devices shall require minimum hand or finger movement. See Section 5.3.2 for location of controls.

The horn shall have controls for each side of the cab for actuation and a three position momentary switch to modulate the sound as required. When the horn is actuated, the bell shall also sound and continue to sound until deactivated. Alerter reset shall occur. The horn sound level shall be 96 dBA, minimum, at a distance of 100 feet forward of the locomotive and meet FRA requirement 49 CFR 229. Pneumatically-operated valve and supply piping sized to handle the required air flow and a cutout cock shall also be provided. The horn sound shall be unique and not easily confused with a truck or automobile horn. The horn shall also be quick acting so that there is no delay in the build-up to full volume when activated. The horn shall be located so that the sound emanates toward the front of that end of the vehicle. The control of the horn shall not be trainlined. The horn shall be an SEPTA standard heated Nathan K5LA horn. Synthesized electronic bell and horn sounds shall be acceptable. The sounds
and dBA level must be similar to SEPTA's existing equipment. The supplier shall submit a minimum of six (6) unique horn tones for evaluation.

The control for the bell shall be a momentary contact rocker switch located on the cab console. The bell shall produce a repeating sound with a one second repetition rate in response to continuous switch activation. The sound level emitted by the bell shall be a minimum of 75 dBA at 50 feet.

5.12.7 Rear View Mirrors and Camera Provision

Each side of the cab shall be equipped with a rear view mirror. The size of the mirror shall be approximately 6 inches by 10 inches and adjustable by 30 degrees on both the horizontal and vertical axis. Mirrors shall be manually accessible from the cab for easy access and adjustment.

Each side shall also be equipped with a rear-view camera that is monitored on desk display. The Contractor shall also provide a space and mounting provision for one (1) camera inside each cab to provide full coverage of the cab interior. The camera shall be connected to the on-board Locomotive Digital Video Recorder System specified in Section 14.

5.13 SANDING

The locomotive shall be equipped with a sanding system. The sanding system shall conform to applicable FRA regulations. The sanding system shall be electrically activated, trainline controlled and pneumatically operated.

The sanding system shall have the following characteristics:

- The system shall be configured to deliver sand to each rail in front of the first axle, depending on direction.
- Sand shall be delivered at a rate of 12 ounces per minute from each nozzle.
- Manual operation shall be controlled by a momentary control on the console.
- Emergency brake applications shall cause an automatic application of sand until the locomotive has received a no-motion indication.
- Control of the sanding system shall be integrated into the design and functioning of the wheel slip, propulsion and braking systems.
- A mechanically operated air cut-out valve shall be provided at each individual sand box.
- Sandboxes are described in Section 3.

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6 HVAC

6.1 HVAC System

There shall be two separate and unitized HVAC units providing heating, cooling, and dehumidification, either roof mounted or located in the center of each Operator’s console and shall have a minimum fresh air flow of 35 CFM. A closeable fresh air damper shall be provided for the crew to reduce air flow as necessary. The HVAC unit shall be designed for easy removal and replacement in less than one hour. Roof mounted units shall be surface mounted over each operating cab in accordance with Section 3.4.3.4. Operator’s console mounted unit installation shall meet the Fire and Life Safety requirements given in Section 2.5.6. Consideration shall be given to the secure mounting of the HVAC unit to the vehicle given the mechanical shock and vibration that locomotives are subjected to during operation. The HVAC units shall also be designed for ease of accessibility and maintenance particularly for air filter replacement. All replacement parts and components shall be commercially available in the U.S. domestic market.

6.1.1 Unit Configuration

The HVAC unit shall be a modular and totally self-contained, hermetically-sealed refrigeration system. As a minimum, the refrigerant system piping shall include a replaceable filter-drier, a moisture indicator/sight glass, a safety pressure relief valve, and high and low pressure cut-out switches. To facilitate replacement without breaking to the refrigerant circuit, all pressure switches and transducers shall be installed on Schrader-type fittings. All control logic shall be contained within the units.

6.1.2 Temperature Adjustability

The HVAC unit shall have adjustable louvers, fan speed controls, and temperature sensors that will enable the Operator to adjust the air flow into and the temperature in the cab. The air supply shall be provided through individual and fully adjustable diffusers for the engineer and the assistant engineer seat locations.

6.1.3 Capacity

The HVAC unit, together with the floor/wall mounted heaters described in Section 6.2, shall be capable of maintaining a cab temperature between 68°F and 75°F with the outside ambient temperatures range of -20°F to 104°F. The refrigeration system shall be capable of providing the full cooling capacity up to 104°F.

The system shall be capable of operating at reduced performance at ambient temperatures between 104°F and 115°F without shutting off on high pressure. At these reduced conditions, the system shall maintain a cab interior temperature 25°F below the ambient temperature.
6.1.4 Controls
The HVAC unit controls shall utilize microprocessor controllers with mechanical power switching relays and contactors.

6.1.5 System Analysis
The locomotive builder and HVAC contractor shall perform a heating and cooling thermal load analysis to establish the required BTU ratings for the system. Consideration shall be given to the elevated temperatures and pressures experienced on the railroad as well as the solar gain through the windows and the heat gains from the equipment room. Temperatures shall be obtained from published ASHRE data for Southeastern Pennsylvania.

6.1.6 HVAC Supply Voltage
The HVAC unit shall be designed to operate on the locomotive 480VAC power supply. If other voltages are required for the control components in the system, any necessary conversion shall be designed into the HVAC unit.

6.1.7 Refrigeration System
The refrigeration system shall utilize a scroll refrigerant compressor. The design of the refrigerant compressor application shall take into consideration the frequent on/off cycling due to power interruptions and the liquid migration that may occur during the off cycle.

6.1.8 Refrigerant
The refrigerant system shall utilize an approved HFC refrigerant. Refrigerants 134A and 407C are acceptable to SEPTA.

6.1.9 Controls
Controls for adjusting the operation of the HVAC system shall be mounted within easy reach of a seated operator. Reporting of pressure and temperature information shall be via a USB connection to a laptop computer running appropriate software. In addition, to gain insight into causes of faults and aid in troubleshooting of HVAC problems, the HVAC controller fault monitoring system shall be capable of recording inside and outside temperatures and saving those records to a log along with any fault codes and time stamps as applicable. The air conditioning system shall be designed to pump down each time the unit shuts off. The design of the unit shall be capable of withstanding sudden extended losses of power and termination of head end power without failures.

6.1.10 Performance
Cooling performance shall be capable of maintaining a cab temperature between 72°F ± 2°F with outside ambient temperatures up to 104°F. Cooling performance shall be capable of pulling down the cab of a heat soaked locomotive from 90°F to 74°F within 15 minutes. Cooling performance shall be capable of pulling down the cab of a heat soaked locomotive from 105°F to 74°F within 30 minutes. The system
shall be capable of operating at reduced performance at ambient temperatures between 104°F and 115°F without shutting off on high pressure. At these reduced conditions, the system shall maintain a cab interior temperature 25°F below the ambient temperature.

### 6.2 Heating

Heating shall be provided by a combination of both forced air heaters in the HVAC unit and wall or floor mounted electrical units. There shall be two separate and unitized forced air wall and/or floor mounted cab heater units (one on the operator side and one on the fireman’s side) or wall and/or floor radiant heat panels for each operating cab. The heating units shall be designed for ease of maintenance and removal/installation. In the case of forced air floor/wall mounted heaters, each unit shall incorporate a minimum of three blower fan speeds and heater outputs. The main heating controls shall be located within easy reach of a seated operator. Both the HVAC unit heaters and the wall or floor mounted heaters shall be protected against over temperature due to the loss of or excessive reduction of the forced air supply or malfunction of the heater controls. The over temperature protection system shall be approved by SEPTA. All exposed surfaces of the HVAC unit, cab side wall heaters, radiant floor or wall panels and air discharge ducts shall maintain a surface temperature not greater that 125°F.

#### 6.2.1 Cab Mounted Heating Elements

The wall/floor mounted heating units shall be sized to provide a minimum cab temperature of 60°F with an ambient temperature of +10°F without the use of the HVAC Unit.

#### 6.2.2 Heating Performance

Heating performance shall be capable of maintaining a cab temperature 70°F ± 2°F with an outside ambient temperature of -20°F. The system shall be capable of increasing the temperature of a 30°F cold soaked cab to 65°F within 15 minutes. The system shall be capable of increasing the temperature of a 0°F cold soaked cab to 68°F within 30 minutes.

Heating performance shall conform to 49 CFR 229.119 for cab comfort.

#### 6.2.3 Heated Windshield

Windshield defrosting shall be provided by electric heaters built into the windshield. A switch with on/off functionality shall be provided. The heater shall be operable only when the cab is energized. The windshield heater shall be protected by a circuit breaker. Defogging shall be done by the HVAC.

#### 6.2.4 Power & Airflow Criteria

The heater power shall be sufficient to provide the required performance without damaging the windshield under any ambient condition. The windshield heater shall clear the windshield of frost or ice formed by 0.010 fl. oz. /in² of water (applied as recommended by SAE J381) within 30 minutes or less at an ambient temperature of -30°F.
6.3 HVAC Systems Testing

The total heating and cooling systems shall be tested in accordance with the requirements given in Section 16.

END OF SECTION
7 LIGHTING AND INDICATORS

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7.2 LED vs. INCANDESCENT/FLOURESCENT

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7.3.1 Controls

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7.4.1.1 Cab Ceiling

7.4.1.2 Console/Timetable Lights

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7.4.3 Miscellaneous Lighting - Locker and Maintenance Access Lights

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7 LIGHTING AND INDICATORS

7.1 GENERAL

The purpose of the lighting system is to allow crew and maintenance personnel to perform their assigned tasks in an efficient, safe, and hygienic manner.

Interior lighting shall be sufficiently flexible to provide adequate and convenient illumination under all ambient lighting conditions from complete darkness to bright sunlight. Lighting in all locations shall be arranged to minimize shadows, avoid glare, and avoid excessive brightness ratios.

All lamps and fixtures shall be suitable for rough duty service found in the normal railroad environment. On internal fixtures, the change out of lamps shall require no tools. External light fixtures shall be possible to change out lamps lamp using only a screw driver.

Unless specified otherwise in this Section, lighting system design and light intensity both on the exterior and in the interior of the vehicle shall meet or exceed the minimum standards defined by AAR RP-040, ADA, and 49 CFR Parts 221 and 229.

The Contractor shall provide drawings of the lighting arrangement for SEPTA review and approval. The location of each lighting fixture, ballast, switch, control, lamp type, and quantity shall be clearly identified.

7.2 LED vs. INCANDESCENT/FLOURESCENT

It is SEPTA’s preference to have LED lighting wherever practical for its application. If such lighting is not found to be feasible as agreed to by both the Contractor and SEPTA, all traditional lighting elements shall be considered to be rough duty cycle as required in Section 7.1, with proven past history of use within locomotives designs and/or meet the specified requirements found later in this section.

7.3 POWER SOURCE

The power sources for lighting shall be 72 VDC nominal when supplied by LVPS or 64 VDC if the battery is not charged, with the ability to power the lights from an external 120 VAC source.

All lighting shall be powered from the Locomotive LVPS system, with each function protected by its own circuit breaker. Battery power shall be provided to maintain lighting during standby and emergency conditions.

Refer to Section 8 for power supply details.
7.3.1 Controls

Local controls shall be provided based on ergonomic operation integrated within the cab console as called out in Section 5.3.2 or as deemed fit for location or function when mentioned within this Technical Specification.

7.4 INTERIOR CARBODY LIGHTING ARRANGEMENTS

7.4.1 Cab

7.4.1.1 Cab Ceiling

The cab interiors shall be equipped with a pair of flush-mounted dust proof ceiling lights each with its own inverter ballast. The light beam shall be controlled to avoid glare on the windshield. A switch shall be provided on the engineer's console. A pushbutton switch shall be installed at the base of each cab ladder which shall cause the cab light to come on for 1 minute, to allow crews to enter an otherwise darkened cab. Lighting shall operate in all lighting modes.

The lighting intensity provided in the operating cab by the ceiling light(s) shall equal or exceed 15 foot-candles measured on the floor and 20 foot-candles measured on the console.

7.4.1.2 Console/Timetable Lights

The Engineer and Assistant Engineer consoles shall each be equipped with an adjustable timetable light, mounted within the console overhang to illuminate the console as a whole and/or the desktop areas of each seating position. Light shall be directed over the minimal area necessary for each light type. A dimmer-type switch shall be provided for each position. Lighting shall operate in all lighting modes.

The timetable light shall provide a maximum of 25 foot-candles, adjustable downward.

7.4.2 Machinery Room

A two system, machinery room lighting scheme shall be provided. One system shall provide the normal walkway lighting and a second system shall be used for maintenance activities (high brightness lighting system).

The normal machinery room walkway lighting shall be powered by the battery bus and the 120 VAC system, and shall supply lighting for aisles and passage ways, lockers, cabinets.

The room(s) shall be equipped with dust-, moisture-, and oil-proof sealed fixtures. Several fixtures shall function as aisle lights for safe passage through the room(s). In addition, a sufficient number of fixtures shall be provided so that essentially all equipment can be serviced.
Both systems shall be reviewed and locations approved by SEPTA. Fixture lens shall be easy to clean. Inverter ballasts shall be able to ignite the lamps down to at least 0°F. Light switches shall be provided at each end of the room on a three way circuit. Lighting shall operate in all lighting modes.

Each system shall be supplied with sufficient intensity for their functions, though minimum aisle lighting shall be sufficient to provide safe passage through machinery room with at least 5 foot-candles measured at the floor.

### 7.4.3 Miscellaneous Lighting - Locker and Maintenance Access Lights

Lighting shall be provided for maintenance of all equipment located in lockers, above the ceiling panels, and in other service areas. Lighting shall be automatically extinguished when ceiling panels or service doors are closed. The lamps and fixtures shall be protected against damage. Fixture design shall not allow dangerous or failure inducing temperatures to develop should the light stay on when the door is closed. The lighting shall operate during all lighting modes.

Equipment servicing light intensities shall be sufficient enough so that all equipment identification tag information and equipment components can be serviced without the need for additional portable lighting.

### 7.5 EXTERIOR CARBODY LIGHTING ARRANGEMENTS

#### 7.5.1 Maintenance Access

Lighting fixture designs shall be designed to allow re-lamping of head, marker or ditch lights within 10 minutes using only a screwdriver. The task shall not require removing a large number of screws or fasteners.

#### 7.5.2 Headlight

Headlight assemblies shall consist of a dual LED headlight unit arrangement at each cab end of the locomotive with optional use of either left, right or both unit operation.

The headlights shall be controlled by the Headlight Selector Switch. The Headlight Switch shall include “Bright/Ditch/Dim/Off” setting positions. The headlight function shall be available in a cab regardless of whether the cab is activated.

Each individual headlight shall be 200,000 candela minimum, with performance measured to meet 49 CFR 229.125.

#### 7.5.3 Ditch Lights

Two LED ditch lights at each cab end shall be located not less than 60 inches apart horizontally and not less than 40 inches above the top of rail. The ditch lights shall be focused horizontally within 15 degrees toward the longitudinal centerline of the locomotive.
Ditch lights shall be controlled via a cab console mounted, 2-position switch allowing the ditch lights to operate in automatic or manual modes.

Each ditch light shall be 200,000 candela minimum, with performance measured to meet 49 CFR 229.133. Contractor shall provide protection for ditch lights from debris hits.

### 7.5.4 Marker Lights

Two LED marker lights at each cab end shall be located not less than 52 inches above the top of rail.

Marker lights shall be turned on via a rotary switch within the switch panel of each cab which will energize the marker light at that end of the locomotive. Marker lights shall include functionality to flash after an emergency brake application.

Each marker light shall be 1,000 candelas, with performance measured to meet 49 CFR 221.14.

### 7.5.5 Number Boards

Two number board lights shall be installed at each cab end of the locomotive on both sides of the headlights. The number boards shall contain and illuminate the locomotive number. Number sign lights shall be illuminated whenever the headlight is on (either bright or dim).

If the Contractor proposes a phosphorescence number board which meets FRA regulation, samples shall be provided for review and approval by SEPTA.

### 7.5.6 Ground Lights

LED ground lights shall be provided near cab side entrance doors to provide light at the roadbed at the base of the ladder. Light switches shall be provided on the exterior at ground level and on the interior near the door entrance within the cab.

The exterior ground level switch shall be maintained in a weather proof switch/box arrangement. Engaging the switch shall cause the both the ground light and cab ceiling light to illuminate for one minute for safe entry into the cab.

Engaging the cab “exit” light switch shall illuminate both the ground lights for easy egress from the cab for one minute, after which both the ground light and cab ceiling light shall extinguish.

Ground lighting shall operate in all lighting modes.

Intensity that shall be made in accordance with the AAR Manual of Standards and Recommended Practices, RP-040, latest revision, and/or FRA requirements with the lighting operating at nominal voltages.
7.6 LAMPS AND BALLASTS

Lighting is preferred to be LED, however, if it is not found to be feasible, the following lamps and ballast requirements must be met.

Fluorescent lighting is preferred over incandescent, wherever it does not compromise lighting quality.

All ballasts shall meet the requirements of UL595 and ANSI C82.

7.6.1 Fluorescent Lamps

The T-8 high efficiency rapid start lamps shall provide basic car body lighting. Other high performance fluorescent lamps may be used as required.

7.6.2 Ballasts – AC

All AC lighting ballasts shall be American-made, high efficiency, 120 VAC input, high power factor, rapid-start units. They shall meet or exceed Federal Law 100-357. Strong consideration shall be given to high frequency electronic units to improve lamp efficiency. The ballast shall not sustain damage from removing a lamp while in operation.

Required features:

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<th>Requirement</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
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<td>0°F or lower</td>
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<tr>
<td>Sound Rating</td>
<td>A</td>
</tr>
<tr>
<td>Class</td>
<td>P</td>
</tr>
<tr>
<td>Power factor</td>
<td>90% minimum</td>
</tr>
<tr>
<td>THD</td>
<td>Less than 20%</td>
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<tr>
<td>Crest factor</td>
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</table>

7.6.3 Ballasts – Inverter

All DC lighting ballasts shall be American-made, high efficiency units, nominal 72 VDC input, rapid start units. The ballast shall not sustain damage from removing a lamp while in operation.

Required features:

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Starting temperature</td>
<td>50°F or lower; 0°F for machine room</td>
</tr>
<tr>
<td>Sound Rating</td>
<td>A</td>
</tr>
<tr>
<td>Input voltage</td>
<td>45 to 86 VDC continuous, self protected against low and high voltage operation.</td>
</tr>
</tbody>
</table>

7.7 LED Lamps

SEPTA will consider LED lighting in certain applications in addition to marker lights, illuminated signs and indicators. LEDs shall have a minimum service life of 50,000 hours.
7.8 SWITCHES

Except as noted, all switches shall be toggle action, MIL-S-3950. All switches shall be clearly labeled with permanent labels, except when operation is obvious, such as switches adjacent to light fixtures.

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8 HEAD END POWER

8.1 GENERAL

Each locomotive shall have an HEP (Head End Power) supply to provide 480 VAC, 60 Hz, three-phase power to train loads and to locomotive APL (Auxiliary Power Locomotive) loads. HEP power shall be train-lined the entire length of the train via two redundant trainlines. Refer to Section 2.3.13. A separate APL inverter may be proposed if required.

Control of power to HEP and APL loads shall be separate and independent.

Except as otherwise noted herein, the HEP system, APL system and battery charger/LVPS system shall conform with IEEE 1476 - IEEE Standard for Passenger Train Auxiliary Power Systems Interfaces. Load analyses shall be performed and presented at design review.

8.2 HEP INVERTER

The HEP supply system shall be equipped with redundancy features such that in the event of single failure in the HEP supply, the system shall automatically switch to an alternative fully rated supply to enable continued supply of HEP power to the train. The contractor shall present the proposed arrangement to SEPTA for review.

8.3 POWER REQUIREMENTS

The HEP supply shall be capable of supplying 1200 kVA (or 1000 kW) on a continuous basis to train loads, plus power as required for APL loads. The actual connected HEP loads shall vary with the number and type of cars in the train. Power factor of connected loads can vary from 0.8 to 1.0.

The rating of APL supply must be consistent with the requirements of the locomotive.

8.4 OTHER ELECTRICAL REQUIREMENTS

- Voltage: 480 Vac three phase nominal +/- 2% at no load (steady state), note the regulation requirement below.

- Applied over the full range of catenary voltage variations

- Total harmonic distortion (voltage output): <5%, with no more than 3% at any single harmonic

- Voltage Dip: 10% maximum departure from the nominal voltage, for no longer than 2 seconds, upon a change in application from 10% to 90% or 90% to 10% of a 1,000 kVA load.
• Frequency: 60Hz nominal +/-1Hz at 480 Vac

• Voltage Unbalance: +/-1% phase to phase

• Voltage Regulation: To be stable and controlled to offset the voltage drop at the end of a long consist, the phase voltage shall have the ability to increase up to a maximum of +5%, at maximum load current. Depending on the actual HEP load, HEP voltage at the receptacles on the locomotive shall be increased as follows:
  - at 0% HEP load: 480 V
  - at 100% HEP load: up to +5% (504V)

  The precise setting shall be determined during design review. This feature shall be controlled by software and shall be disabled by default. SEPTA shall have the ability to enable this feature if so desired.

• The HEP output shall be electrically isolated from the inverter by a transformer

• The HEP supply shall not be damaged by a short circuit

### 8.5 Wayside Power Stations

Power to the HEP system shall also be possible by plugging the locomotive trainline into one of the existing SEPTA wayside power stations. Design provisions of the HEP must ensure that the locomotive HEP and Wayside supplies cannot be connected to each other. Sufficient interlocking and protection shall be provided such that no equipment (on board or wayside) is damaged when the wayside power plug is connected to the locomotive. Simultaneous powering of HEP loads from locomotive inverter and wayside power station shall not be possible and if attempted, no equipment damage or safety hazard shall occur. Refer also to Section 2.5.

SEPTA shall supply electrical schematics of wayside power stations if needed.

### 8.6 Ground Detection

The HEP supply shall have a ground detection system to detect grounds on the train. The HEP neutral shall not be directly grounded. A resistance connection to ground to establish a reference for the ground detector is preferred. The presence of a ground fault shall be immediately indicated. The HEP system shall continue to operate normally in the presence of a single ground fault on its output.

### 8.7 Protective Functions

The HEP system shall be protected against the following conditions and shall automatically shut down to prevent equipment damage in the event of an occurrence of any of these conditions:
- Short circuit on output
- Loss of one phase
- Over temperature
- Over or under voltage
- Frequency out of tolerance
- Overload

### 8.8 CONTROL PROVISIONS

All controls for applying 480 VAC power to the trainlines shall be operated automatically. The following features are required methods of controlling HEP and APL.

- It shall be possible to manually isolate the HEP and APL equipment and remove power to train or machine room circuits at any time.

- The APL and HEP systems shall operate independent of the status or utility of the locomotive propulsion or braking systems.

- The APL inverter (where used) and HEP inverter shall be designed for a soft-start (ramp up slowly with voltage and frequency) to limit high inrush loads.

- The HEP power to passenger cars shall only be applied to trainlines when:
  - Both Right and Left side trainline safety circuit is complete
  - There are no other voltages present on the HEP trainlines
  - If the locomotive speed is 5 mph or higher, HEP power shall be applied regardless of trainline safety circuit.

- HEP power shall be immediately removed from trainlines when:
  - Loss of trainline safety circuit with speed below 5 mph
  - Output voltage above 505 VAC, 60 Hz for more than 5 seconds
  - Frequency outside of tolerance for 5 seconds or more
  - Output current overload
  - 480 VAC isolation switch is placed in off position.
• The HEP power shall only be restored after an indication of a left and right trainline safety circuit restored is received, and followed by an HEP reset from the Engineer’s cab control.

8.9 BATTERY CHARGER/LVPS

Each locomotive shall be equipped with a low voltage battery charger that shall operate directly from the HEP or APL 480 VAC, 60 Hz, 3 phase power. The battery charger shall be compliant with IEEE Standard 16, and all standards referenced therein.

The battery charger shall use solid-state components and be microprocessor controlled with self-diagnostic capability.

The battery charger shall have sufficient capacity to charge the battery while supplying full load 72 VDC to the locomotive.

The battery charger shall be able to charge a fully discharged battery to 80% of capacity in less than 5 hours.

Fuses shall not be used as a service disconnect. A manually operated main disconnect switch shall be provided.

The battery charger shall not be damaged and shall be fully protected against the following conditions:

• Open circuited battery or wiring
• Short circuited battery or wiring
• Battery ground fault
• Temperature sensor fault
• Sustained under voltage operation
• Input phase loss
• Reversed battery connections
• System overload
• Voltage or current over limit.

The battery charger shall be interfaced with the locomotive diagnostic system.

Battery charger shall charge the batteries under any mode of operation including locomotive connected to a wayside power station.
8.10 BATTERY

Each locomotive shall be equipped with a storage battery of SEPTA approved type for emergency and standby power. It shall be recharged by the battery charger and be of fire resistant material. The battery shall be of a low maintenance design, with no reconditioning actions required more frequently than 5 years. Sufficient reserve electrolyte shall be provided to allow for approximately one year of in-service use, before having to add water.

Only batteries with successful proven service on rail vehicles shall be permitted. The battery shall conform to the requirements of APTA PR-E-RP-007-98R1.

Batteries shall be the Nickel Cadmium type with an Ampere-Hour rating sufficient for the required duty, including margin for temperature variations, expected charging duty cycle and degradation over the battery lifetime. Calculations shall be presented during design review to demonstrate that the battery capacity is adequate for the required duty. The nominal voltage shall be 64 VDC with a nominal on charge voltage of 74 VDC at 77°F.

Alternately, the batteries may be the sealed Pb type with a minimum 450 Ampere-Hour rating, with no electrolyte or maintenance actions required more frequently than 5 years. The nominal voltage of sealed Pb type batteries shall be 64 VDC with a float charge of 72 VDC.

Battery capacity shall be sufficient such that in the event the LVPS is inoperative, the battery shall supply power as a minimum to the following critical loads, for up to two hours:

- Train Radio
- Communications System
- Headlights and Number lights
- Marker lights
- Safety lights, such as ground lights and engine room walk-through lights
- Cab Gauge Lights
- Cab Signal/ATC and PTC System
- Event Recorder System
- Central Diagnostics
- Electronic Air Brake control
- Emergency Exit Lighting
- Engineer’s Display Unit
- Locomotive Control (Supervisory, Traction and Auxiliary) Computers

8.11 LOW VOLTAGE POWER SUPPLY NETWORK

The battery and battery charger shall power the LVSN.

This network shall supply low voltage power to all locomotive systems. All loads on the LVSN shall be specified to operate normally over the full output voltage range of the battery charger/LVPS under all normal operating conditions.

A load-shedding system shall be included to shed non-essential loads and maintain emergency power to critical systems. An external indicator shall be provided to clearly indicate when the load shedding
system is active. The location of this indicator shall be subject to approval of the Engineer. The Contractor shall analyze the low voltage power requirements and design a load shedding scheme in compliance to FRA regulations and APTA recommended practices.

8.12 SHOP POWER SUPPLY RECEPTACLES

Shop power receptacles shall be provided on the locomotive to provide 120 VAC, 60 Hz for lighting and convenience outlets.

A minimum of one 120V duplex outlet shall be provided in each cab. A minimum of one 120V duplex outlet shall be provided near the center of the machine room. The location of convenience outlets is subject to review by SEPTA.

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9 PROPULSION AND DYNAMIC BRAKING

9.1 PROPULSION and DYNAMIC BRAKING

Each locomotive shall be equipped with a propulsion and dynamic braking system. A separate propulsion inverter, traction motor and gear unit shall power each axle of the locomotive. All propulsion and dynamic braking control shall be on a per-axle basis.

Dynamic braking energy shall be maximized and first be regenerated into the HEP loads and catenary (if receptive) in the form of regenerative braking. If the catenary is not fully receptive, then the dynamic brake shall be blended with the friction brake to meet the brake effort demand. This blending shall be transparent to the operator in all modes of operation, including but not limited to, service brake applications and safety control enforcement, for smooth, continuous and jerk-free operation, except in an emergency brake.

The propulsion and HEP inverters are to be identical, if possible. In the event of auxiliary inverter failure, another inverter shall automatically be switched to provide HEP.

Except as otherwise noted herein, power converter equipment shall conform to IEC 61287, Power converters installed on board rolling stock. Except as otherwise noted herein, all electrical equipment shall conform with IEC 60077 - Railway applications - Electric equipment for rolling stock.

9.2 GENERAL

9.2.1 All Axles Motored

Propulsion for each locomotive shall be provided by three-phase alternating current squirrel-cage induction traction motors, one per axle.

9.2.2 Individual-Axle Control

Propulsion control shall be arranged to modulate propulsion system tractive effort on a per-axle basis. To that end, each traction motor shall be powered by a dedicated variable-voltage, variable-frequency (VVF) inverter.

9.2.3 Equipment Isolation for Failure Modes

In case of equipment failure the failed equipment shall be completely isolated (Both + and – sides) from the remaining good equipment. The idea is to provide maximum redundancy for increased mission reliability. The isolation method shall be automatic and annunciated via the TOD (Train Operator Display). The arrangement adopted shall reflect accepted design practices in the rail industry and shall satisfy the following criteria:
A. No single functional failure of a Traction Motor or Inverter:

- Shall disable electric traction on more than one axle;
- Shall deprive the locomotive of any of its electric braking power beyond that which can be continuously made up by friction braking within the thermal constraints of the friction braking equipment;
- Shall deprive the locomotive of normal control of service friction braking on any truck;
- Shall deprive the locomotive of adhesion management on any truck.

B. No two independent functional failures of a Traction Motor or Inverter

- Shall deprive the locomotive of normal control of service friction braking on more than 50 percent of its axles;
- Shall deprive the locomotive of adhesion management on more than 50 percent of its axles.

C. No functional failure of any VVVF inverter or traction motor shall disable electric traction on any axle beyond that directly affected.

D. The Engineer does not intend to prohibit brief operational interruptions at the locomotive level during which the equipment protects itself against a failure in progress or reconfigures itself following a failure.

E. A vehicle architecture wherein the propulsion system shares one or more line converters with the auxiliary power system may be proposed.

9.2.3.1 Analysis

The Contractor shall provide an analysis justifying the exact system architecture chosen. The justification shall address such issues as EMC, cost, cooling, complexity, reliability, availability and fault tolerance, weight, and maintainability, and shall demonstrate that, considering all factors, the chosen architecture is not inferior to other reasonable alternatives. Alternative arrangements for fault tolerance within the propulsion system will be considered by SEPTA as long as the Contractor demonstrates system reliability equal to or greater than that detailed in this specification.

9.2.3.2 Approval

The system architecture shall be subject to approval by the Engineer.

Circuitry associated with each propulsion inverter may, depending on the approved architecture, include, but not be limited to, the following components/subsystems:

- Means for connection to the output of the main transformer
• Contactor(s)

• Cooling. If blower motors are used all such motors shall be protected from over temperature. The use of embedded temperature sensors is permitted. Forced ventilation may be utilized subject to SEPTA approval.

• Filter capacitor charging circuit(s)

• Filter inductor(s)

• Rectifier(s)

• Filter capacitor bank(s)

• Brake chopper(s)

• Three-phase VVVF inverter(s)

• Sensors for control and monitoring (e.g., voltage, current, temperature, speed, as required)

• Protective devices

• Traction motor(s)

Each axle’s propulsion unit shall operate independently. Failure or mis-operation of one unit shall not adversely affect operation of the others.

Each axle’s propulsion unit shall utilize the traction motors to provide electric braking.

Each propulsion control logic unit shall be able to provide a command for friction brake tractive effort (Friction Brake Command) to the friction brake system described in Section 11. Alternative division of functions between propulsion and friction braking may be proposed based on demonstrably-superior performance.

Each propulsion control logic unit shall detect wheel slip and correct spins and slides by modulating propulsion, electric braking and friction braking, and by actuating friction brake slip control magnet valves as required, in conformance with Section 11 and as described herein. Alternative division of functions between propulsion and friction braking may be proposed based on demonstrably-superior performance.

Each propulsion unit shall incorporate a Local Diagnostic and Test System (LDTS) to perform self-test, fault detection, relevant signal recording, status logging, and self-diagnosis, and shall communicate such information to the Central Diagnostic System (CDS) as described herein and in Section 14.

• All parameters of propulsion system performance, including friction brake control, if applicable, shall conform to Section 2 and all requirements contained herein. The Contractor shall ensure
that the propulsion equipment used is capable of meeting all applicable performance requirements.

The Contractor shall prepare detailed performance calculations and curves to demonstrate compliance with the Technical Specification and, if the Contractor is not the propulsion manufacturer, the manufacturer’s requirements.

9.2.4 Input Filter and DC Link

A common 2f (twice the catenary frequency) filter shall be used on each locomotive. The switching for the appropriate catenary voltage and frequency shall be under automatic control. The filter and DC link shall be designed to provide a solid, low impedance voltage source for the propulsion inverters. It shall also limit harmonic currents on the catenary to values consistent with the EMI requirements of Section 2. The inductor used for this filter may be located inside the main transformer coolant tank at discretion of supplier.

1. The propulsion system shall be protected by a separate input filter consisting of at least one L-C pole, in addition to the main DC link capacitor and any inductor(s) associated with the line converter. The input filter shall be designed to mitigate conducted EMI and to protect the converters against catenary line transients. This input filter shall lie entirely between the main transformer and the line propulsion inverters. With the possibility of multiple traction inverters per line filter, careful consideration must be given to the effects of the number of truck/axle inverters cut-in/cut-out on propulsion system line filter performance (e.g., movement of poles/resonant frequencies, attenuation changes, etc.).

2. Each rectifier contactor shall be provided with a charging contactor and charging resistor(s) which shall limit charging current and input filter voltage overshoot to levels which shall preserve the integrity of the propulsion power equipment under all conditions, and such that recovery from such overshoot shall not delay operation of the inverter.

3. Filter design shall comply with the requirements of Section 2, including requirements for filter bleed resistors, indicators and restricted access.

4. Charging circuitry may be mounted in the inverter enclosure or may be located in a separate enclosure along with the contactors.

5. Inductor(s) forming part of the filter shall, if not mounted in the main transformer tank, be convection cooled. If not located in the main transformer tank, the inductor(s) shall be designed to prevent entry of dirt and magnetic particle build-up on high voltage surfaces. Adequate cooling must be provided.

6. Inductors with multiple taps providing the inductance values required for different modes may be proposed for the Engineer’s approval. Each inductor shall be designed to obtain the required input filter characteristics and to obtain the inductance values required for optimum line converter operation, EMI mitigation, and transient protection, as appropriate to the propulsion system architecture. No periodic tuning by SEPTA maintenance personnel shall be required.
7. The DC link shall include a 2f filter (“tank circuit”) to suppress the second harmonic of the line frequency, unless shown not to be necessary.

9.3 RECTIFIERS

Each rectifier shall operate as a four quadrant rectifier to accept or return power from the catenary line. They shall provide a regulated voltage for the DC link. The rectifiers shall also be used to control power factor and harmonic currents. The number of rectifiers and main transformer secondary windings shall be selected by the supplier. The rectifiers shall use IGBT switching.

9.3.1 Power Factor

The input power factor shall be controlled to as close to unity as feasible, and over as wide an operating range as feasible. The Contractor shall submit the estimated power factor and operating range for approval by Engineer.

9.3.2 Notch Filter

A software controlled notch filter is required to limit conducted harmonic emission at critical signal frequencies. The system shall be designed to have this provision.

9.3.3 General

The propulsion system shall be provided with four-quadrant line converter(s) that shall function in 12 kV ac (+12.5%, -30%)/25 Hz, 12.5 kV ac (+20%, -30%)/60 Hz, and 25 kV ac (+10%, -30%)/60 Hz modes of operation. The tolerance for frequency shall be ±1%. The line converter(s) shall enable regeneration of energy to the line over the voltage ranges specified in Section 2.

9.3.4 Motoring and Electric Braking

In both motoring and electric braking, each line converter shall function as a four-quadrant rectifier to maintain the line power factors as close to unity as possible. In electric braking, each line converter shall further function to regulate regenerative current delivered to the line, allowing the DC link voltage to be maintained at an optimal level for electric braking operation regardless of the line voltage.

9.4 PROPULSION INVERTERS

There shall be one IGBT propulsion inverter per axle. Each inverter shall have individual axle control.

Control of propulsion and electrical braking shall be via microprocessor based control that is service proven. The Contractor shall provide a complete and detailed description of the control system for review and approval by SEPTA.

The inverters shall be fully compatible with the traction motors.

The propulsion inverters and auxiliary inverters shall be identical.
The inverters shall be fully compatible with the propulsion controls so that the power outputs always conform to the control logic commands.

The inverters shall incorporate temperature sensors. For protection against inverter over-temperature due to excessive duty cycles, restriction of cooling air, or any other cause, the propulsion controls shall reduce inverter duty to prevent inverter temperature from exceeding allowable limits. The reduction in inverter duty shall be managed in an approved fashion that gives priority to motoring.

9.5 OVER-VOLTAGE PROTECTION

There shall be over-voltage protection on each link between the 4Q converters and the inverters. The over-voltage system shall protect the capacitors, IGBTs, and other components from excess voltage stress due to voltage surges and high current interruptions.

1. The over-voltage system shall be sized and fully compatible with the SEPTA infrastructure and the worst case interruptions to locomotive currents such that the locomotive does not exceed the specified performance jerk rate.

2. Any operating frequency of the over-voltage system shall be stable and selected to minimize EMI and ensure EMC.

3. A chopper may be utilized for voltage limiting only.

9.6 TRACTION MOTORS

9.6.1 Motors design

Each locomotive shall have one traction motor per axle. The traction motor shall be force air ventilated with filtered air. Traction motors may be truck frame mounted or carbody mounted. Traction motors shall be three phase, AC, squirrel cage type design with copper windings and rotor bars. The traction motor shall be designed in accordance with IEC Standard 60349-2, Electric Traction – Rotating Electrical Machines for Rail and Road Vehicles – Part 2: Electronic Converter-Fed Alternating Current Motors, or IEEE STD. 11-2000. Traction motor flux levels shall be compatible with EMI/EMC requirements of Section 2.6.3.1 and 2.6.3.2. The traction motor shall have a safe operating speed that is compatible with all performance requirements of Section 2.2.7.1 with fully worn wheels.

Although the Engineer strongly prefers rolled-frame stator construction, a “frameless” motor may be proposed by the Contractor subject to inclusion of a full wrapper capable of containing stray flux and preventing all forms of EMI and CSI caused by stray flux from the motor. Degradation of motor internal components by airborne contaminants shall be precluded by the design of the motor and its internal components, by appropriate air inlet location and, if necessary, by provision of approved inertial separators appropriate to the design. Air filters shall not be of the replaceable media type. The design of air inlets, filters, and ducts shall preclude the impairment of cooling air by accumulations of snow, ice, dirt, leaves, etc. under all conditions specified in Section 2, and shall take into account the aerodynamic effects associated with operation of the locomotive at all positions in a train.
The motor shall have a safe speed that meets the requirements of Section 9 of IEEE STD 11-2000 and Section 6.3 of IEC 60349-2. In the event of discrepancies between these two standards, the requirements of IEEE STD 11-2000 shall govern unless otherwise advised by the Engineer.

The motor, when operated under the conditions specified in Section 2, shall remain within the temperature range designated for stationary armature windings in Section 5, Table 1, of IEEE STD 11-2000 with Class C winding insulation.

The completed motor frame with insulated coils shall be given at least two vacuum-pressure impregnations with an approved silicone-type resin or approved equal with a temperature rating class equal to or greater than the temperature rating class of the motor winding insulation. If silicone is used, one vacuum pressure impregnation is permitted.

The rotor cage shall be of copper alloy bars with brazed or welded rings.

The rotor and cooling fan shall be dynamically balanced separately so that, after they are assembled, net dynamic unbalance measured at each bearing is less than 1.0 inch-ounce without any balancing following assembly. Balance-correcting weights shall be metal and shall be permanently installed.

Traction motor power connections shall be made by means of double bolted connections to bus bar terminals built into the motor. The bus bar terminals shall be protected by a terminal housing integral to the traction motor and provided with access plate(s) as needed. To the maximum extent possible, the terminal housing shall be located out of line-of-sight of ATC receivers in order to minimize Cab Signal Interference (CSI). The cable(s) shall pass the terminal housing by means of watertight strain relief cable connector(s).

The terminal housing and access plates shall be robust and reliably watertight. The bolted connections shall utilize a minimum of two bolts each. The bus bar terminals and bolted connections shall provide adequate creep and strike distances. The bus bar terminals shall be clearly and permanently marked and shall be positioned or physically designed so as to reject inadvertent crossing of properly terminated traction motor cables. The bus bar terminals and housing shall be arranged to prevent loose hardware, such as nuts and bolts, from falling into the motor or becoming concealed within the housing. The housing shall be arranged to drain.

Neither traction motor leads nor knuckle joint connectors shall be used.

### 9.6.2 Traction Motor Cabling/Connections

Cables from the traction motors on each truck shall run from the terminals on the traction motors to a socket-pin-type quick-disconnect, or approved alternate, mounted on a support attached to the carbody in the vicinity of the truck.

Cables from the traction motors to the quick-disconnects, and from the quick-disconnects to the inverters, shall take the form of sheathed, shielded, twisted-triplet cables with drain wires. The drain wires shall be carried through the quick-disconnect. All cable terminations shall be clearly marked.
Traction motors, including electrical connections, shall be identical and shall be interchangeable among all positions on all motor trucks.

All traction motor cabling shall be routed out of line-of-sight of ATC receivers in order to minimize cab signal interference (CSI). The plan for traction motor cabling and other measures (if any) to mitigate CSI shall be submitted for approval.

The current value used in determining the minimum size of motor leads shall conform to NFPA 130-2010, Section 8.6.3.

9.6.3 Traction Motor bearings

The motor shall be equipped with insulated, anti-friction bearings, lubricant seals, and lubricant cavities. Lubricant cavities shall have a volume sufficient for 500,000 miles (7 years) of operation before requiring re-lubrication. Bearing housings shall be readily accessible to permit addition and purging of lubricant without de-trucking.

The bearings shall have an ANSI/AFBMA L10 rating life of one million miles. Bearing seals shall be labyrinth-type. Lubricant shall be approved by the Engineer.

9.6.4 Traction Motor Mounting/Couplings

Traction motors shall be isolated by resilient elements from equipment below the primary suspension, including the gear unit if the latter is axle-mounted.

Bolts shall be Grade 5, and shall be tightened with a torque wrench to a repeatable torque value. Grade 8 bolts, if used, are not to be plated, but corrosion protection shall be required.

The motor shall be provided with lifting lugs or with means for attaching a lifting device(s) such as a tapped hole(s) for a lifting eyebolt(s). The motor shall be stable when placed on the floor.

The motor shall be provided with safety straps, tabs, or hangers to prevent the motor from falling in the event of failure of the primary motor mounts. The lifting lugs may be adapted to perform this function.

The vibration of any traction motor, detached and supported on resilient mountings, providing at least 0.25 inch static deflection, shall not exceed 0.0015 inch peak-to-peak displacement at the motor bearing housing and at the motor mounting points while the motor is rotating at any speed between 50 percent and 100 percent of the maximum normal operating speed. Each assembled motor shall also meet the vibration requirements of IEEE STD 11-2000, Section 13.2.

The traction motor design shall minimize audible noise resulting from high frequency current switching patterns when operating from the propulsion inverter. Motor noise shall conform to the requirements of IEEE STD 11-2000, Section 2.11.1.

Embedded over-temperature sensors shall not be permitted. For protection against excessive dead car scenarios, the propulsion control shall determine an over temperature condition, in which the traction motor winding temperature rises 27 degrees F (15 degrees C) above its normal maximum temperature,
by calculating motor power, and shall decrease motor duty to prevent motor temperature from exceeding this level. The reduction in motor duty shall be managed in an approved fashion that gives preference to motoring but does not reduce electric braking to a degree that would compromise overall service braking performance. Alternative temperature rise limits and protection strategies may be proposed for approval.

9.6.5 Traction motor cooling

The traction motor cooling air inlet, if used, shall be designed in such a way that leaves and other debris are prevented from entering the machine, and shall be such that leaves and debris that have accumulated against the inlet naturally fall clear by gravity whenever the motor is not rotating. The means proposed to meet this requirement shall be submitted for approval.

9.7 GEAR UNIT

There shall be one gear unit per axle.

9.7.1 General

Each motored axle shall be driven by a gear unit which shall be a parallel drive designed and manufactured for bi-directional service. Helical-type gears shall be used. Gear box construction shall be cast steel, cast iron, or welded fabrication using materials as specified in Section 15. Material and fabrication process to be approved by SEPTA.

The gear ratio shall be selected to provide the performance specified in Section 2.2.7.1 and 2.2.7.2 and shall conform to established railcar gear design practice.

The motor and gear unit drive and mounting arrangement provided shall meet the specified noise, vibration, ride quality, shock loading and maintenance requirements of the Technical Provisions.

All gear units shall be interchangeable and unitized as long as they can be changed out as a complete unit.

The gear unit assembly and associated drive components shall be tested for compliance to IEC 61373.

The gear unit and associated drive components shall be designed to survive structural and dynamic loads for not less than 2.5 million miles of normal service. A stress and fatigue analysis shall be submitted for review and approval.

The gear unit seals shall not require servicing or replacement more frequently than once every second wheel replacement.

The gear unit design shall be based on existing service-proven applications operating in similar environments.
9.7.2 Gears

Gears shall be designed and installed for a minimum inspection and adjustment interval of 500,000 miles. Break-in shall be done prior to delivery. No break-in shall be required at SEPTA.

Gears shall have a minimum fatigue design life of 2.5 million miles with no degradation of performance. Gears shall be fabricated from high-quality gear steel, designed and heat-treated/hardened in accordance with AGMA 2004-B89, Gear Materials and Heat Treatment Manual. Gears shall be carburized to a hardness of RC 55 to an approved depth greater than 0.040 inch.

9.7.3 Bearings and Seals

The gear unit shall be equipped throughout with tapered roller bearings, or approved equal, which shall require a minimum inspection or adjustment period of 500,000 miles. The bearings shall be selected and applied to have an ANSI/AFBMA L10 rating life of 1 million miles. The bearings shall be commercially available and readily stocked.

External bearing shaft seals shall be the labyrinth type, with supplemental sliding contact seals, if necessary to keep high velocity splashed water from entering the gear units and to prevent leakage of gear oil. The life of the seals shall be equal to or greater than the bearing life.

9.7.4 Lubrication System

The gear unit shall be oil-lubricated using approved lubricant selected to meet requirements of the OEM.

The gear unit shall be designed with sufficient baffles, dams, sufficiently-sized passages and similar structures to ensure an adequate flow of lubricant to all bearings and gears under all conditions of rotation, speed, load, temperature and weather described in the Technical Provisions, including continuous operation in either direction at maximum speed over the life of the case without blockage from debris. The unit shall be designed so that adequate lubrication shall be provided to all bearings and gears under the most severe operation conditions and to prevent moisture infiltration into the lubricant.

With proper maintenance, the gear unit shall not lose oil except as vapor, shall not require lubricant level check at less than 30,000 mile intervals and shall not require lubricant additions at less than 60,000 mile intervals. Seasonal changes of lubricant oil shall not be required. Lubricant changes shall not be required more frequently than as determined by oil analysis.

The gear unit shall have sufficient oil capacity for adequate cooling. All gear lubrication shall be in accordance with the applicable sections of AGMA Standard 9005-E02.

The gear unit shall have at least one oil drain opening located at the lowest point in the case or sump. A readily-accessible magnetic filler plug shall be provided, with an opening at least 2 inches in diameter arranged to provide an indication of oil level, prevent overfilling, and located for easy filling. The filler plug may be nonmagnetic, provided that a magnet shall be included in the gear unit, located for maximum contact with the lubrication oil and easily removable for inspection and cleaning. All such plugs shall be safety wired and shall be located to prevent damage by obstacles on the track.
The gear case shall be provided with a readily-accessible oil sight gauge for use by maintenance personnel. Minimum and maximum level indicators shall be provided and both levels shall be visible in the sight glass or by a dipstick. A dirt cover shall be provided over the sight glass to provide protection from debris strikes. Sight glass must be replaceable.

The quantity and grade of lubricant shall be indicated on the filler plug or on the gear case adjacent to the filler plug opening.

The gear unit lubrication system shall be readily accessible without de-trucking and shall be designed to prevent overfilling.

### 9.7.5 Maintenance

The gear case shall be provided with removable and accessible oil-tight and air-tight inspection covers with suitable gaskets for visual inspection of the gears. An adequately-bolted and gasketed opening shall be provided for inspection and routine maintenance. A 1.5 inch plug shall also be acceptable for this purpose.

All gaskets must be easily replaceable with minimum effort and time required.

Gear unit components requiring repair or replacement shall be readily accessible with a minimum amount of gear unit disassembly.

Parts requiring replacement or adjustment prior to realizing the service design life of the system shall be individually replaceable.

Disassembly, reassembly and routine maintenance shall be possible to the maximum extent with tools and items of maintenance equipment in common usage.

### 9.7.6 Mounting

The gear unit shall be suspended from the truck frame with a flexible connection to the axle-mounted quill or shall be axle-mounted with a resilient mount at the opposite end of the axle. If the latter, the resilient mount shall be the vertical-bolt type using bonded elastomeric pads at the tongue of the gear unit and at the point of suspension from the truck. Alternative mounting schemes may be presented for Engineer approval. An application analysis shall be provided for the selection of material used for the bonded elastomeric pads and submitted to the Engineer for approval. The selection of the elastomer shall be in accordance with the requirements in Section 15.

The drive train design shall not increase the stiffness of the axle suspension within the truck.

### 9.7.7 Coupling

A double internal-external, self-aligning, gear-type coupling shall be provided between each gear unit and the associated traction motor. Alternative coupling designs may be proposed.
The coupling shall be suitably balanced to minimize noise and vibration produced at locomotive speeds up to 125 mph with fully-worn wheels. When newly assembled, the coupling alignment shall not be offset more than permitted by the worst-case stack up of manufacturing tolerances.

Lateral, vertical, longitudinal, and angular motion of the arrangement shall be provided for in the design.

Suitable seals shall be provided.

### 9.7.8 Transient Torque Loadings

The Contractor shall submit, for approval, an analysis demonstrating the ability of the entire drive train to withstand without damage extraordinary transient loadings resulting from inverter “shoot-through,” direct three-phase short-circuit of the traction motor leads, and any other comparable mis-operation or failure. The Contractor shall ensure that the design of equipment conforms to all requirements identified by this analysis.

### 9.8 TRACTION CONTROL

#### 9.8.1 Control Functions

Control interface characterization not otherwise or explicitly specified in the Technical Provisions shall be in accordance with IEEE STD 1475-1999 for Type III interfaces as specified therein.

Locomotive acceleration rates at a given percentage of tractive effort demand shall be limited by the control system to no more than the values indicated in Figure 5.

**Figure 5**

**Acceleration Rate vs. Speed**

A discrete propulsion Power Enable trainline shall be provided. The propulsion/friction brake logic shall not permit power application, regardless of Master Controller Tractive Effort command, unless the Power Enable trainline is energized. In addition, an under-speed trainline shall be provided which shall
implement speed control braking as commanded by the SEPTA PTC system. The propulsion/friction brake logic shall permit neither power application nor the development of braking effort less than that corresponding to a trainline command for the speed control braking rate specified below, regardless of Master Controller Tractive Effort command, unless the Under-speed trainline is energized. Commands for braking at rates greater than the speed control braking rate shall not be affected by the Under-speed trainline.

Inverter operation shall continue during coasting; that is, coast shall be a “zero-slip coast.” The purpose of this requirement is to ensure that dc link voltage is maintained at all times when the car is in motion, and to promote rapid response to mode change commands.

The propulsion system design shall be such that all propulsion units in a train are in the same mode (propulsion, coast or brake) at all times, within the limits of the control system response times defined in Section 2.2.8.

Provisions shall be made for isolating a failed propulsion unit. The line contactor (and charging contactor, depending on charging circuit configuration) shall be opened to ensure the cut-out propulsion unit is isolated from other circuitry.

The Contractor shall prepare a detailed description of propulsion system operation, including schematics, description of control and protective features, diagnostics, inverter/brake chopper operation, and other system features described in this Section.

### 9.8.2 Direction Control

The propulsion system design shall be such that propulsion and electric braking tractive effort is applied as required by trainline direction commands.

The propulsion controls shall continuously monitor the validity of trainline direction commands and shall inhibit accelerating tractive effort whenever an invalid trainline direction command is received and train speed is below 3 mph.

### 9.8.3 Wheel Slip / Slide

The wheel slide system shall be active at all times to prevent flat wheels. This applies to all locomotives including an un-powered locomotive being towed.

The propulsion system shall provide a wheel slip / slide detection and correction system. This system shall provide adhesion control to ensure at least 85% of the possible adhesion is obtained by the cars.

The propulsion system shall interface with the friction braking system for slide control in braking as described in braking Section 11.

Correction for differences in wheel diameters shall be automatic.

This system shall protect against locked wheels and generation of wheel flats spots.
Malfuction of this system shall not result in loss of braking on any axle.

Sanding shall be activated upon detection of wheel spin or slide. Sanding shall cease when this condition is corrected.

The slide control system shall function under all operating conditions and when the locomotive experiences traction motor failure as well as when the locomotive is “dead in consist” and battery power is made available.

The Contractor shall provide a detailed description of the slip / slide system for review and approval by Engineer.

9.8.4 Interlocks

9.8.4.1 Traction Interlock:
Propulsion tractive effort shall be inhibited whenever a passenger car side door is unlocked or open, as required by Section 6.2.1. The contractor shall provide a bypass switch in each cab to override this feature in the event of a system failure. In addition, the Contractor shall provide a door opened indication of the actual locomotive cab door but not linked to the traction interlock function. This indication will notify the engineer if the cab door is open in either the operating or non-operating end of the locomotive.

When stopped (i.e., below the no-motion detection threshold), it shall be necessary to have the Master Controller in a coast or service brake position in order initially to make up the Traction Interlock. Once the interlock is made up, the circuit shall be latched such that subsequent movement of the Master Controller out of the coast or brake zone does not de-energize the interlock.

Once the Traction Interlock circuit is established, traction power may be applied. The Traction Interlock shall remain latched until the next time a side door is sensed as being open and/or unlocked.

Once above the no-motion detection threshold, de-energization of the Traction Interlock shall inhibit propulsion, but shall not apply brakes. In addition, it shall not be necessary to return the Master Controller to the brake zone in order to re-establish the interlock, provided that train speed remains above the no-motion detection point.

9.8.4.2 Emergency Brake Interlock
Traction power shall be removed by redundant and reliable means whenever emergency braking is commanded or applied. This traction power removal shall be implemented using fail-safe principles to the maximum extent possible. The design shall be subject to approval by the Engineer.

9.8.4.3 Friction Brake/Parking Brake Interlock
Propulsion tractive effort shall be inhibited whenever a parking brake is applied anywhere in the train, as required by Section 11
Propulsion tractive effort shall be inhibited when friction brakes are applied anywhere in the train, except as required by Section 11.

**9.8.5 Bypasses**

9.8.5.1 **Traction Interlock Bypass**

Interlock on a train basis in the event of a failure in the interlock circuit.

The Traction Interlock bypass shall function only in the controlling cab.

9.8.5.2 **Friction Brake/Parking Brake Interlock Bypass**

A bypass pushbutton, located on the console, shall be provided in the cab to bypass the Friction Brake/Parking Brake Interlock on a train basis in the event of a failure in the interlock circuit. The pushbutton shall be functional only in an active cab, but in any Master Controller handle position and, when pressed momentarily, shall latch the bypass function which shall remain latched until the Master Controller handle is keyed out.

When a brake release has been commanded and there are one or more trucks with friction brakes or parking brakes applied, the Central Diagnostic Panel (CDP) shall display the precise locations(s) of the brakes which are applied.

**9.8.6 Rollback Protection**

Upon a brake-to-propulsion mode transition at zero speed, release of the friction brake effort shall be limited to keep just enough brake effort to prevent the train from rolling on the most severe grade on the line. The friction brake application for roll-back protection shall not inhibit the application of propulsion tractive effort. During tractive effort increase, the friction brake effort limit shall be reduced proportionally to maintain the anti-rollback effort.

Upon propulsion tractive effort becoming sufficient to hold or move the vehicle on the worst-case grade, the friction brake shall be released. The release of friction brakes shall be accomplished smoothly to prevent jerking. Roll-back protection shall not become active again until brakes are again applied at zero speed.

After a time delay sufficient to ensure friction brakes are fully released, or at a pre-defined, low-speed threshold, the friction brake-propulsion interlock shall be reinstated so that a subsequent application of friction brakes shall inhibit propulsion tractive effort as described above.

Alternative methods of implementing roll-back protection may be proposed. Regardless of the method of implementation, roll-back protection shall not interfere with uncoupling operation.
9.8.7 Power Braking

At speeds above 5 mph, propulsion power shall be blocked and blended dynamic braking enabled when the brakes are applied. A red “NO POWER BRAKE” indication shall be given on the engineer’s console or TOD. Restoration of propulsion power shall be made by returning throttle handle to “IDLE” position and releasing brakes.

At speeds below 5 mph, propulsion power shall be available when brakes are applied for an adjustable interval. The default interval is 21 seconds and shall be adjustable via PTU between approved limits.

9.8.8 Protection

The propulsion system shall incorporate protection functions that prevent damage or incorrect operation resulting from the following causes, at a minimum:

- Inverter/converter over current;
- Inverter/converter semiconductor and/or heat sink over temperature;
- Traction motor overload;
- Traction motor over temperature, based on calculated traction motor temperature;
- Traction motor over speed;
- Traction motor gear coupling separation;
- Incorrect connection of traction motor leads (i.e., phase reversal or incorrect phase sequence);
- Wheel diameter differences, up to and including the greatest wheel diameter difference that is physically possible;
- Ground fault, sensed as an imbalance of supply and return current, the threshold of which shall be set as necessary to avoid nuisance trips;
- Open traction motor phase;
- Charging resistor open circuit;
- Line or dc link over voltage; (also see Section 9.5)
- Failure of line contactor(s) to open when commanded;
- Excessive line ripple current and
- Actuation of any protective function shall be annunciated to the diagnostic system.
Transient abnormal or fault conditions shall be reset automatically. Automatic resets shall be counted and limited; repeated occurrences of the same malfunction over short time intervals may be treated differently to optimize the protection.

The Contractor shall use the results of wayside power characterization testing (Section 2) in designing system protective features.

Propulsion controls shall be designed and programmed to provide protection of propulsion system power components. The control logic shall not command a power device to interrupt more current than it is rated for, less margin, nor to operate when its applied voltage is in excess of its rating, less margin. Reception of both forward and reverse commands, or detection of any other invalid command, shall inhibit propulsion or result in some other approved action. Upon detection of an abnormal condition which might result in damage, the controls shall actuate capable circuit interrupter(s) provided in the power equipment. Manual reset of fault condition shall be controlled to prevent equipment damage to any propulsion system component or sub-system.

**9.8.9 Car Wash Mode**

A car wash mode shall be provided to enable the Operator to maintain proper speed through the car wash facility. The car wash mode, when activated, shall smoothly limit the speed of the train to 3 mph. The car wash mode shall be activated and canceled by a control on the console. It shall be necessary for the Master Controller Key Switch to be in ON position for the car wash mode to be activated. It shall be necessary for the train to be stopped and the Master Controller handle to be in FULL SERVICE BRAKE or EMERGENCY BRAKE for the car wash mode to be canceled, except that the car wash mode shall be automatically canceled whenever the Master Controller Key Switch is moved from the ON position.

**9.8.10 Diagnostics**

Each propulsion control unit shall incorporate a Local Diagnostic and Testing System (LDTS) as specified in Section 14. The propulsion control, monitoring and diagnostic system shall be submitted for SEPTA approval.

The propulsion system shall perform a self-test of the control logic each time control power is turned on, and shall perform a self-test of the power control equipment when high voltage is first applied once control power is turned on.

Upon application of high voltage, the line filter capacitor charging curve shall be monitored to assure the integrity of the line switch and filter for both input protection and conducted EMI mitigation. Each filter pole (where more than one) shall be monitored separately. The propulsion system design shall ensure that line filter integrity is monitored sufficiently often to comply with the assumptions of the EMI Safety Analysis required in Section 2.6.

Upon closure of the line switch, feedback from sensors in the power equipment shall be monitored to assure the integrity of the power control components in their initial states. Power switching devices shall each be actuated while feedback from sensors in the power equipment is monitored to assure the integrity of the power control components in their active and quiescent states, prior to using these devices for propulsion or electric braking.
While operating the power equipment for propulsion or braking, all available feedback signals shall be continuously monitored so that any abnormal operation or condition may be detected and reacted to as early as possible.

Any abnormal operation, actuation of a protective function, or failure of self-test shall be logged in an incident log which is stored in non-volatile memory, as an occurrence of one of a predetermined set of incidents, each such incident in the set having a unique code and descriptor to maximize the usefulness of such record. In addition, from said predetermined set of incidents there shall be identified a subset which shall require an oscillograph-type recording (“snapshot”) of applicable signals specifically defined for each such incident. The length of the recording shall be specifically defined for each such incident, as well.

All available signals which contribute to the diagnostic functionality of the propulsion system shall be continuously monitored and recorded in the control logic equipment to facilitate capture of oscillograph-type recordings as required.

Upon the occurrence of an incident for which an oscillograph-type recording (“snapshot”) is defined, the required data in signal memory shall be copied to a memory area designated for incident recordings. Signal recording shall not be interrupted while the “snapshot” is being copied.

The memory used for the incident log and the incident recordings shall have an uninterruptible power supply such that the memory shall be retained for at least thirty (30) days with control power removed. Energy storage device(s) or system(s) in this power supply shall be automatically recharged whenever control power is present. This device must have a 20 year minimum life.

Upon incident recordings exceeding the amount of memory available for their storage, the oldest recording(s) shall be overwritten as necessary so that new ones can be saved. The amount of memory shall be sufficient to hold at least fifty (50) snapshots.

The menu of diagnostic incidents shall be arranged such that incident definitions may easily be deleted and new incident definitions may easily be added. Furthermore, each set of signals to be recorded upon the occurrence of each such incident, and the duration of the recording, shall be capable of easy revision.

The propulsion system shall also utilize all available information to provide intelligent evaluations of failure and mis-operation incidents to indicate the probable cause of failure or mis-operation. The propulsion system shall also utilize all available information to intelligently evaluate system operation and indicate imminent component or system failures.

Each propulsion control unit shall continuously compute and record the cumulative kilovolt-ampere hours, kilovolt-ampere reactive hours (kvars) and kilowatt-hours of energy in the following flows:

- Contact wire to propulsion system;
- Propulsion system to auxiliaries, and contact wire (regeneration).
• Contact wire or propulsion system to auxiliaries.

The recorded values shall be accessible by use of the PTU. Also, real time current shall be available for viewing on the PTU and as analog outputs for external instrumentation.

Each propulsion control unit shall have at least ten (10) analog and sixteen (16) digital outputs for external instrumentation. This interface shall be designed for instrumentation with high impedance inputs but shall tolerate short circuits without affecting the operation of the propulsion system. Each analog output shall be programmable to address any control and/or feedback signal of an analog nature; each digital output shall be programmable to address any digital-type control and/or feedback signal.

A standing power test feature shall be provided, which shall be accessible from the Maintenance Screen on the CDP. The test feature shall allow a low-power test of all propulsion systems on a train while at standstill with full service braking applied. Test results for each truck shall be displayed on the CDP after completion of the test. An automatic timeout feature shall be incorporated, as required, to protect the propulsion system from thermal damage.

A standing test of the control logic for electric braking shall be provided. This test shall be accessible from the Maintenance Screen on the CDP. The test feature shall provide a test of as much of the electric braking function as is possible at standstill. Test results for each truck shall be displayed on the CDP after completion of the test.

Speed sensor failures shall be detected and communicated to the Central Diagnostic System (CDS) and shall be annunciated on the Central Display Panel (CDP) in the active cab.

Sustained locked wheel conditions shall be detected and communicated to the Central Diagnostic System (CDS) and shall be annunciated on the Central Display Panel (CDP) in the active cab.

The propulsion system shall also contain additional diagnostic functions as required by Section 14 for ease of maintenance and repair.

The propulsion control logic shall function as the Local Diagnostic and Test System (LDTS) for the friction brake system, as specified in Section 19. The friction brake (LDTS) monitoring and diagnostics shall include the following:

1. Monitoring of friction brake system control components (e.g., transducers, magnet valves).
2. Monitoring and logging, as appropriate, of brake cylinder pressures and air spring pressures.
3. Monitoring and verification of correct friction brake system response to commands issued by the FBCU.
4. Monitoring of the interface to the propulsion logic along with verification of correct response to the command received from the propulsion logic.
5. Recording of failure “snapshots” as defined in Section 14.

7. Reporting of summary status and failure information to the Central Diagnostic System (CDS).

8. Reporting of brake cylinder pressures on command from the CDS. Brake cylinder pressures shall be monitored by the LDTS by means of transducers connected downstream of the dump valve and brake cylinder cutout cock.

### 9.8.11 Odometer

To measure car mileage, an odometer function shall be provided as part of the propulsion logic.

It shall not be possible to reset the odometer except by special means. Odometer operation and reset means shall be included in the Contractor’s propulsion system description.

It shall be possible to read the odometer both from the CDP and the PTU.

It shall be possible to visually read the odometer without battery power present.

### 9.8.12 Kilowatt-Hour Meter

A kilowatt-hour meter shall be installed to record the following:

1. Total energy input into locomotive in kW-Hrs.
2. Total energy consumed in kvars by locomotive.
3. Regenerative energy returned to catenary in kW-Hrs
4. Net energy consumption of locomotive in kW-Hrs.

It shall not be possible to reset the kilowatt-hour meter except by special means. Operation and reset means shall be included in the Contractor’s propulsion system description.

It shall be possible to read the kilowatt-hour meter both from the TOD and the PTU.

The memory of the kilowatt-hour meter must be non-volatile and be retained with loss of battery power.

### 9.8.13 Accelerating Line Current Limits and Adjustment

There shall be provision, by means of software parameters, to set limits to accelerating line current on a per-inverter basis or a per-locomotive basis. Separate sets of limits shall be defined for 12 kV ac/25 Hz operation, 12.5 kV ac/60 Hz operation, and for 25 kV ac/60 Hz operation. Each inverter shall act at all times to limit its line current to the lowest applicable value among those defined in the following three paragraphs. Performance of each inverter shall be the maximum possible within the active line current limit after deducting measured auxiliary loads. Performance shall be designed for stability under all
conditions of auxiliary loading and changes in auxiliary loading. Each of the current limiting settings shall be PTU-adjustable and non-volatile.

### 9.8.14 Initial Accelerating Tractive Effort Limits and Adjustment

There shall be provision by means of software parameters to limit the initial accelerating tractive effort. Separate settings shall be defined for 12 kV ac/25 Hz, 12.5 kV ac/60 Hz, and 25 kV ac/60 Hz operations. Each of the three tractive-effort settings shall be PTU-adjustable and non-volatile. The range of adjustment for each setting shall be from zero to the effort required to obtain the performance required in Section 2. The default value for each setting shall be the maximum value. Each car's inverters shall be configured to the default settings when placed in revenue service and shall revert to the default settings in the event that modified settings are lost for any reason. Default settings may be altered from those stated herein by agreement between the Engineer and the Contractor.

### 9.8.15 Electric Braking Fade Speed Limits and Adjustment

There shall be provision by means of software parameters to set the speed at which electric braking fades out and is replaced by friction braking. Separate settings shall be defined for 12 kV ac/25 Hz, 12.5 kV ac/60 Hz, and 25 kV ac/60 Hz operations. Each of the three fade-out speeds shall be PTU-adjustable and non-volatile. The range of adjustment for each setting shall be from maximum car speed to the minimum fade speed provided by the propulsion system. The default value for each setting shall be the minimum fade speed provided by the propulsion system. Each car's inverters shall be configured to the default settings when placed in revenue service and shall revert to the default settings in the event that modified settings are lost for any reason. Default settings may be altered from those stated herein by agreement between the Engineer and the Contractor.

### 9.8.16 Regenerative Line Current Limits and Adjustment

There shall be provision by means of software parameters to set limits to regenerative line current on a per-inverter basis or a per-locomotive basis. Separate sets of limits shall be defined for 12 kV ac/25 Hz, 12.5 kV ac/60 Hz and 25 kV ac/60 Hz operation. Each inverter shall act at all times to limit its line current to the lowest applicable value among those defined in the following three paragraphs. Performance shall be designed for stability under all conditions of auxiliary loading and changes in auxiliary loading. Each of the current limit settings shall be PTU-adjustable and non-volatile.

### 9.8.17 Regenerative Line Voltage Limits and Adjustment

There shall be provision by means of software parameters to limit the maximum regeneration line voltage and to set the regeneration taper voltage. Separate settings shall be defined for 12 kV ac/25 Hz, 12.5 kV ac/60 Hz and 25 kV ac/60 Hz operation. All values shall be non-volatile.

Maximum regeneration line voltage: The range of adjustment for each setting shall be from zero to the setting required to obtain the performance described in Table 9-1 below. The default value for each setting shall be the value shown in Table 9-1.

Regeneration taper voltage: The range of adjustment for each setting shall be from zero to 97 percent of the prevailing setting of the maximum regeneration line voltage, unless a more restrictive limit is
required in order to ensure stability. The default value for each setting shall be the value shown in Table 9-1.

### 9.8.18 Regeneration Disable

There shall be provision by means of software parameters to disable regeneration to the line on a per-inverter basis or a per-locomotive basis. Separate setting shall be defined for 12 kV ac/25 Hz, 12.5 kV ac/60 Hz, and 25 kV ac/60 Hz operations. All settings shall be PTU-adjustable and non-volatile.

### 9.8.19 Wheel Size Compensation

Not Used.

### 9.8.20 Dynamic Functional and Performance Requirements

#### 9.8.20.1 General

1. **Line Voltage**
   - The nominal, minimum, and maximum line voltages shall be as defined in Section 2. The propulsion system shall not be damaged by continuous exposure to line voltages between 0 and the maximum voltage, nor by exposure to higher transient voltages which occur on the contact line. Operation with continuous line voltages up to the maximum voltage shall be considered routine. To ensure stable operation with respect to line voltage, hysteresis shall be provided at transition points as necessary.

2. **Power Factor**
   - The propulsion system shall maintain the line current power factor at unity, plus zero (0) minus approved tolerance(s) (which may be a function of instantaneous train speed), at all times.

3. **EMI and Harmonics**
   - The propulsion system shall comply with the requirements of Section 2 as regards EMI and line current harmonics.

#### 9.8.20.2 Acceleration

1. **Performance and Line Current**
   - The propulsion system shall have the capability to provide the acceleration performance required in Section 2 without exceeding the line current limits stated below.

2. **Line Voltage**
   - The propulsion system shall operate in acceleration as shown in Table 9-1, below, as a function of the supply voltage. Specified performance per Section 2 shall be achieved uniformly over the
entire range indicated in Table 9-1 for specified acceleration performance; that is, neither initial tractive effort nor Base Speed shall vary with line voltage within that range.

3. Line Current Limit
   Accelerating line current shall not exceed the line current limits established in accordance with this section.

4. Tractive Effort Limit
   Tractive effort in acceleration shall not exceed the tractive effort limits established in accordance with Section 2.2.7.2.

<table>
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<tr>
<td>Reference (see Section 2.2.3.1): Minimum sustained voltage</td>
</tr>
</tbody>
</table>

* The 25 Hz section of catenary supply may have harmonic voltage distortion as high as 40% due to connected loads and frequency converters.

** Details on system hysteresis to be submitted to the Engineer for approval.
9.8.20.3 Electric Braking

1. General
   - As specified in Section 2, service braking shall be provided normally by electric braking. Electric braking shall be available at all times above a speed sufficient to support motor excitation from the motion energy of the car, regardless of the presence or absence of primary power.
   - Electric braking shall at all times be regenerative.
   - Fade-out speed: The fade-out speed in electric braking shall be as established in accordance with Section 2.2.7.8 and Section 12.

2. Regenerative Braking Performance
   - Regeneration Priority: Regenerated power shall be consumed first by the auxiliary loads, to the extent that they are able to absorb that power. The balance of regenerated power shall be directed to the line, to the extent that it is able to absorb that power.
   - Line Voltage: The propulsion system shall operate in regeneration as shown in Table 9-1, below, as a function of the supply voltage.
   - Line Voltage Limit: Line voltage in regenerative operation shall not be raised by the propulsion system above the line voltage limits established in accordance with Section 2.2.8.1.

9.8.20.4 Regenerative Braking Function

Energy produced as a result of regenerative braking and returned to the catenary shall be limited; the limit shall be software settable and initially set to five (5) megawatts. Auxiliary loads shall be designed to function without damage, mal-operation, or interruption at the inverter line filter voltages developed. Regenerative braking shall be capable of continuous operation under these conditions.

The energy produced by regenerative braking shall always be available for use by the vehicle’s auxiliary loads.

If a phase break/dead section or primary voltage transition is anticipated in electric mode, the propulsion system shall switch from motoring to a low level of regenerative braking to support auxiliaries and maintain dc-link capacitor charge. Auxiliary support shall be provided without interruption regardless of the operating mode of the propulsion equipment at the moment the gap is encountered, up to and including operation at full accelerating tractive effort. Propulsion system characteristics shall be coordinated with the design of the auxiliary loads to ensure that this requirement is met. The level of braking effort produced shall be selected to avoid problems getting through gaps at low speeds. Operation of this function shall be speed-dependent, as follows:
1. General
At higher speeds, where sufficient braking power is available without excessive braking torque, both auxiliaries and the dc-link shall be supported. This function shall be automatically disabled below a speed established via a software parameter. The software parameter shall be PTU-adjustable and non-volatile. This speed shall default to, and be initially set to 3 mph.

The system shall continue to maintain dc link capacitor charge down to the lowest speed practical.

Transitions in and out of motoring shall be smooth to avoid jerking.

2. Friction Brake Command
The propulsion system shall be responsible for calculating the friction brake tractive effort requirement and shall output Friction Brake Command signals on a per-truck basis to the friction brake system. The friction brake tractive effort requirement is the braking needed, in addition to the achieved electric braking, to accomplish the correct deceleration rate on a per-truck basis. Alternative arrangements may be proposed and are subject to SEPTA approval.

Friction braking is controlled on a per-truck basis as described in Section 11. Friction Brake Command for the loco shall be provided by two or more propulsion control logic units, one primary and the other(s) secondary, arranged in such a way as to meet the fault-tolerance requirements. The propulsion logic control units shall be arranged to avoid inadvertent contention between Friction Brake Command signals.

In the event that the propulsion system becomes unable to provide electric braking tractive effort on a given truck equal at least to that able to be provided by the friction brake system, all electric braking on that truck shall be discontinued and the entire truck shall revert to friction braking. The slip control magnet valves described in Section 11 shall be used to prevent friction brake application on the other truck on the car if friction braking is not required on that truck, inshot being waived in that case. The slip valve magnet valve control circuit employed for this purpose shall be downstream of the slip control magnet valve control circuits associated with adhesion management and shall be able to be energized only when the car is not in emergency braking. The propulsion system shall continue to provide accelerating tractive effort on each axle where it retains the capability. Alternative arrangements may be proposed and are subject to SEPTA approval.

The Friction Brake Command shall be continuously variable or with resolution consistent with all applicable accuracy requirements.

Each propulsion control unit shall calculate and update its Friction Brake Command output on a continuous basis or with a cycle time not to exceed 50 milliseconds.

The propulsion system shall manipulate the Friction Brake Command in conjunction with electric braking and the slip control magnet valves to correct and minimize slides, as specified in Section 11.
The propulsion system Friction Brake Command shall provide in-shot brake cylinder pressure during braking when friction braking is not commanded as a result of sufficient electric braking effort being applied.

The Friction Brake Command generated by the propulsion control units shall incorporate jerk-limiting, speed taper, and blending, such that no further numerical processing of the Command is required to be performed by the friction brake control unit.

Alternative architectures, with different division of control functions between propulsion and braking, shall be considered.

3. Friction Brake Running Test
   The propulsion system shall include provision to perform a running test of friction brakes only. This test function shall be accessible only through the PTU, and shall automatically cancel once the PTU is disconnected. When this test function is activated, electric braking shall be inhibited on the entire train, and all braking shall be by friction brake only.

**9.8.21 Control Logic**

   a. Propulsion controls shall be microprocessor-based.

   b. Propulsion controls shall interpret trainline commands including, but not limited to: direction; acceleration and deceleration and level of acceleration and deceleration command; power enable; service braking; penalty braking; and emergency braking, and provide the necessary signals to the propulsion inverters and friction brake control unit to obtain the requested performance.

   c. Propulsion controls shall provide self-test and self-diagnostic functions as well as power equipment test and diagnostic functions as described in 9. Self-tests shall operate in a non-interfering manner such that normal system operation is not disrupted by self-tests.

   d. Programs shall be stored in re-writeable, non-volatile memory such as flash EEPROM.

   e. There shall be an easily-accessible communication port for verifying and changing the control software. It shall take no more than five minutes to completely reload the software and rewrite the program memory. Password protection shall be included in the software update function to prevent unauthorized field reprogramming.

   f. There shall be an easily-accessible communication port for connecting a portable interface unit (PTU). It shall take no longer than ten seconds to connect the PTU and access and display the propulsion control equipment status.

   g. The control logic shall be completely electrically isolated from the power equipment. Control/power circuit interface devices shall be rated for at least 2,500 Vdc and 3,500 Vac rms. Such interfaces shall be designed to minimize the effects of common-mode potentials and such noise and other interferences inherent in power switching equipment.
h. The control logic equipment may be located in the inverter enclosure, but shall in any case be physically separated and isolated from the power equipment and power wiring.

i. The control logic equipment shall be securely mounted in an environment-proof enclosure designed for safety, maintainability, accessibility, and easy removal and installation of the equipment.

j. The control logic equipment for both trucks may be located within one housing.

k. The control logic shall provide high impedance input interfaces for the trainline signals which are connected in parallel among propulsion control units and/or other systems.

l. The control logic shall provide low impedance input interfaces for the trainline signals which are connected in series among propulsion control units and/or other systems.

m. It shall be the Contractor’s responsibility to ensure that valid trainline signals can be transmitted and received in any operating train length from two to 18 cars, as well as in any train operating under emergency duty conditions, including trains of up to 20 cars.

n. Failure of any number of propulsion control logic units in a train of any length shall have no effect on trainline signals or diagnostic or other communication signals and shall not affect any other system on the train, other than inevitable effects on friction brake control and inevitable effects of reduced propulsion and electric braking.

o. Propulsion controls shall also provide all the functionality assigned to the propulsion system by the Technical Specification.

### 9.8.22 Speed Sensor

Each axle shall be fitted with a pulse-generating speed sensor which shall be installed on the traction motor and shall sense the rotation of a toothed gear mounted on the motor shaft.

Each speed sensor shall provide both speed and direction feedback to the propulsion controls at all speeds down to a standstill.

The speed sensors shall be hermetically sealed in a stainless steel case. The active face of each sensor shall be smooth with no protruding elements and shall be encased in a seamless stainless steel cover or approved equivalent. The cable shall be molded into the sensor such that the sensor and cable are one piece.

All speed sensors shall be fully interchangeable without shimming or other mechanical adjustment. It shall be neither necessary nor possible to adjust the gap between the sensor and the gear tooth. The speed sensor case shall be shouldered and the mounting plate shall be precision milled to facilitate installation of the speed sensor with no need for adjustment. The speed sensors shall be mechanically keyed to ensure proper insertion in order to provide correct direction feedback.
Speed sensors shall be located to provide the maximum protection, for both the sensor and its wiring, from flying objects under the car. All speed sensors shall be easily accessible for inspection and replacement with trucks attached to vehicles over maintenance pits or on jacks, and with trucks sitting by themselves on the floor.

Speed sensor wiring harnesses shall be designed to avoid low-hanging loops and routing that may lead to cable damage from objects along the wayside. Speed sensor wiring shall not be routed along the truck. The design must allow easy removal and replacement of speed sensor with minimal removal of cable length, cleats or clamps.

All speed sensing gears, toothed wheels, or similar devices shall be mounted so as to ensure that the speed measuring device cannot indicate speeds other than the actual speed under all conditions except massive drive train damage.

Electrically shielded cable shall be used from the sensors to the carbody and shall be encased in a flexible sheathing. The carbody end of the cable shall be fitted with a quick-disconnect fitting that provides a watertight seal around the connection and to prevent fatigue of the wire. The wiring shall be dressed and supported on the truck and carbody as necessary to prevent chafing and fatigue failure.

Speed sensor failures shall be detected and shall be distinguishable from locked axle conditions.

9.8.23 Contactors

The propulsion system shall be provided with one or more line contactors to make and interrupt power during normal operations. The line contactor may be mounted in the inverter enclosure or may be located in a separate enclosure.

All contactors shall be electrically operated. Pneumatic contactors are prohibited.

Contactor capability shall be coordinated with main transformer and input protective device capability.

The contactor shall be designed for a minimum of one million operations with a minimum contact life equivalent to a minimum of five years of normal operation. The Contractor shall provide an analysis documenting tip life.

The contactor shall include an arc chute to safely guide the arc away from the opening current-carrying contacts.

Venting shall be provided to prevent ozone build-up.

Source and return power for the contactors shall be interlocked such that an emergency brake application de-energizes the contactors.

The contactor(s), its control, and associated equipment shall be arranged to limit instantaneous in-rush currents under all operating conditions to a value that shall not cause failure or deterioration of any component. Any means adopted to achieve this shall not materially interfere with locomotive performance under conditions of intermittent collector contact, as with an icy overhead wire.
Contactors used to isolate defective rectifiers, choppers or inverters shall completely isolate the defective components on both positive and negative sides.

9.8.24 Equipment Location and Ease of Maintainability
To the greatest extent possible major propulsion equipment that is located in the machine room shall be designed to minimize the need to remove roof sections for replacement. Speed sensors for propulsion control shall be mounted on the traction motor and designed for easy replacement and accessibility. No shimming or adjustments are permitted for speed sensor installation and replacement.

9.9 HIGH VOLTAGE EQUIPMENT
Each locomotive shall be equipped with a pair of pantographs rated for the voltage, speed and operating performance as described in Section 2.2. The high voltage shall be bussed between pantographs. The locomotive shall also have a Lightning Arrester, Vacuum Circuit Breaker (MCB), Surge Arrester (as required), potential transformer and pantograph lock-down and grounding switch.

Contractor shall provide provisions for “fall protection” on both sides of each pantograph consisting of an eyelet that a lineman can readily attach to. Definition of eyelet shall be provided by SEPTA. Fall protection shall be in accordance with OSHA 1910.66 APP “C.”

9.9.1 Pantograph
The pantograph shall be a single arm Brecknell-Willis type of light weight tubular construction configured for pneumatic raise and auto drop operation with damping to the extent needed to ensure proper tracking. The pantograph shall be Brecknell-Willis Part No. 29500G or SEPTA approved equivalent.

9.9.1.1 Operating Heights
The operating range of the pantograph shall be from 15 feet at minimum to 24 feet at maximum.

9.9.1.2 Contact Force
The pantograph tension shall be 22 pounds nominal.

9.9.1.3 Speed
Maximum operational speed 125 MPH, but qualified at 135 MPH.

9.9.1.4 Direction
Bi-directional.
9.9.1.5 Current Collection Head

The collector head shall be standard as per specified Brecknell-Willis Part No. 29500G.

9.9.2 Mounting Insulators

The pantograph shall be mounted using TYCO HVIB-0360-12-085-007 multi-skirted resin insulators or equivalent as agreed to by SEPTA, which shall be readily accessible for cleaning. Electrically live portions shall have adequate clearance to the roof.

9.9.3 Control and Operation

9.9.3.1 General

Pneumatic-raise from main air system, battery operated auxiliary air compressor.

9.9.3.2 Pantograph Pole

A pantograph pole shall be provided to manipulate the pantograph during emergency situations and shall be of sufficient length, strength and dielectric quality to permit safe and satisfactory use with an energized catenary. The pole shall be the same as used on ALP-44 and ALP-46 locomotives, manufactured by Hastings Fiberglass, Part Number SH-250, “25 foot TEL-O-POLE Hot Stick” or approved equal. The pole shall be retractable and measure about 5 feet when fully retracted to allow for easy storage in a cabinet located in the car vestibule.

9.9.4 MCB (Main Circuit Breaker) Vacuum Circuit Breaker

All locomotives shall be provided with a service-proven, electrically operated vacuum circuit breaker rated for the supply voltages given in Section 2.2.8.1. The vacuum circuit breaker shall normally remain closed, except when commanded to open by the protective devices in the various circuits as recommended by the propulsion apparatus manufacturer and approved by the Engineer.

The main circuit breaker shall be a TYCO HVCB16BN020 or approved alternate. SEPTA will also consider alternative electric main circuit breakers.

9.9.5 Back-up Components

9.9.5.1 Auxiliary Air Compressor

An auxiliary air compressor shall be provided on each locomotive to provide compressed air to raise the pantograph. It shall be driven from the locomotive battery. A reservoir of sufficient capacity for three pantograph operations shall be provided.

The auxiliary air compressor, pneumatic system shall be designed to prevent failure from freezing and shall have the capability of self purging any accumulation of water.
9.9.6 Lightning Arrester

A lightning arrester shall provide transient voltage protection for the main transformer and potential transformer. A single arrester for all catenary voltages is preferred. If this is not feasible, dual arresters with suitable switching means shall be considered for approval. The selection of this arrester must be coordinated with the design of the main transformer to provide maximum protection from transient voltages caused by lightning strikes, MCB operation or wayside equipment.

9.9.6.1 Transient Voltage Analysis and Study

The Contractor shall perform an analysis of the degree of protection provided by the lightning arrester for the main transformer from high transient voltages on the catenary system. The results of that analysis shall be submitted to Engineer for approval before final selection of protective devices is made.

9.9.6.2 Transient Voltage Filter

A roof-mounted transient voltage filter shall be provided if the results of the above analysis and study deem it necessary to ensure sufficient protection to the main transformer.

9.9.7 Potential Transformer

A potential transformer (PT) shall provide an output voltage that is proportional to the pantograph voltage. The output shall be a lower voltage such as 100 volts (or some other feasible level for control purposes) with 25 kV on the primary. The rating shall be at least 30 VA. This transformer shall also be used to measure and record the catenary voltage and must not saturate below 90 kV @ 25 Hz. The potential transformer shall be protected against damage in the event of a short circuit on its output wires.

9.9.8 Grounding Switch

A manual lock-down and grounding switch shall be supplied for each pantograph. This switch shall be capable of being operated near the roof hatch area and have protection against false operation. Determination of the final location shall be approved by SEPTA. Visual verification of switch position shall be possible from ground. A protective system for pantograph lock down and grounding shall be provided. The Contractor shall provide a detailed description of this system for review and approval by SEPTA.

9.9.9 Main Transformer

Each locomotive shall have a main transformer. Its purpose is to step-down the catenary voltage to a lower value suitable for use by the propulsion rectifiers/inverters and the HEP System. There shall be multiple secondary windings.
9.9.9.1 General

The main transformer shall be a single-phase grounded system compatible with voltage/frequency combinations specified in Sections 2 and 9.

The transformer shall withstand without damage the primary voltage transients and interruptions due to substation switching, operation through phase breaks, pantograph bounce, ice accumulation, catenary system faults, and other such conditions. The basic insulation level (BIL) shall be at least 200 kV. High voltage connections shall have a minimum BIL rating of 170 kV.

The transformer input impedance shall be such that there shall not be undue loading of the catenary system with inrush current following such voltage interruptions.

The transformer shall meet all the requirements of the latest revision of IEC 60310.

The transformer, including the tank and all incorporated windings and magnetics, shall be designed to minimize the generation of inductive EMI emissions and the coupling of EMI into track circuits.

Telephone Interference Filters (TIFs) shall be provided to ensure no interference with any communications networks along the SEPTA right-of-way, unless it is demonstrated that the TIFs can be eliminated with no compromise to propulsion system performance, including without limitation the optimal control of line power factor. TIFs shall be subject to the EMI/EMC requirements of Section 2 with the associated design and analysis documented in the EMI Safety Analysis and EMC Design Reports.

The transformer shall be designed to operate without maintenance for a minimum of 15 years.

The Contractor shall submit the transformer and inductor design calculations and drawings for approval.

9.9.9.2 Propulsion Windings

The propulsion windings shall be of sufficient rating to supply the continuous and overload traction power requirements as specified in Section 9.

The quantity and arrangement of windings shall be appropriate for interface with the line converters.

The Contractor’s design shall account for the fact that, for certain fault conditions, the protective response of some loads is to short circuit their input and apply a short circuit across the transformer windings. Therefore, the mechanical bracing of the windings shall be designed so that the transformer can absorb such repetitive short circuiting without damage.

9.9.9.3 Auxiliary Winding(s)

The auxiliary winding(s), if used for HEP power shall be of sufficient rating to continuously supply the HEP requirements. Refer to Section 8 for auxiliary system load descriptions.

The Contractor’s design shall account for the fact that, for certain fault conditions, the protective response of some loads is to short circuit their input and apply a short circuit across the transformer windings. Therefore, the mechanical bracing of the windings shall be designed so that the transformer
can absorb such repetitive short circuiting without damage. SEPTA will consider alternative arrangements.

### 9.9.9.4 Cooling

1. **General**
   The transformer shall be of the liquid-immersed, self-cooled/forced-air-cooled/forced-liquid-cooled, class OA/FA/FOA type. All materials, including insulation and gasket materials, shall be compatible with the coolant. Transformer shall be sealed.

2. **Coolant**
   The coolant shall be reviewed and approved by SEPTA. The Contractor shall ensure that the coolant supplied meets the requirements of the U.S. Environmental Protection Agency at the time of delivery. Mineral oil or other low temperature fire point fluids are prohibited. If silicone or ester based oil is used, the winding temperature rise shall not exceed known standards.

3. **Coolant Pump**
   The coolant pump shall be driven by a totally enclosed squirrel cage induction motor taking power from the auxiliary power system. The pump motor shall be readily accessible for maintenance and replacement. Pump motors shall not have transformer oil-cooled windings. Service valves shall be provided for pump removal. A method to visually verify pump rotation shall be provided. Over temperature protection shall be provided for all pump motors. Use of embedded temperature sensors is permitted.

4. **Heat Exchanger**
   The heat exchanger shall be manufactured of copper or aluminum. The heat exchanger shall be designed so as to be able to be cleaned without being removed and shall have secondary filtering system to prevent radiator clogging. If a secondary filtering system is not offered, such system must be approved by SEPTA.

5. **Fans**
   All fan blades shall be dynamically balanced and free from vibration. The fans shall be equipped with guards complying with US DOT regulations for safety and providing the fan and heat exchanger with adequate protection from flying objects. Fans shall be protected against clogging by snow or ice.

6. **Fan Motors**
   The heat exchanger fans shall be driven by TEFC squirrel cage induction motors equipped with long life No-Field-Lubrication (NFL) sealed bearings. The bearing life shall be a minimum of eight years without servicing. The motors shall be powered from the auxiliary power system. Over temperature protection shall be provided on all fan motors. Use of imbedded temperature sensors is permitted.

7. **Coolant Pressure Gauge**
   The transformer shall be equipped with a gauge for checking coolant pressure and checking coolant pump rotation. The gauge shall be easily readable from the side of the locomotive, without requiring a service pit. The gauge shall be protected from flying objects.
8. Coolant Level Gauge
   The transformer shall be equipped with one liquid-level sight gauge, TEDECO MS248 “High Contrast” Type or approved equal. The gauge shall have no moving parts and shall indicate both the hot and cold range from low to full. The gauge shall be easily readable from the cab side of the car, without requiring a service pit. The gauge shall be protected from flying objects.

9. Flexible Hose or Couplings
   Any flexible hose or coupling is subject to review and approval by SEPTA.

10. Replacement of Entire Transformer
    It shall be possible to replace the entire transformer without requiring removal of the coolant. Valves shall be located at the main transformer on both the inlet and outlet sides, and between the oil pump and heat exchanger. The transformer shall be a complete and removable unit.

11. Sampling and Topping-Up
    The coolant system shall be so arranged that coolant sampling and coolant topping-up can be readily completed with the transformer in its normal position on the locomotive;

12. Coolant Replacement (Draining and Refilling)
    Coolant replacement shall be required only at scheduled transformer overhaul; as part of a major repair; or in the event of abnormal compromise to the tank seal. The coolant system shall be so arranged that coolant replacement can be readily completed with the transformer in its normal position on the locomotive.

9.9.9.5 Protective Devices

1. Interlocking
   Interlocking shall be provided to prevent the application of propulsion power when the transformer cooling fans are inoperative (i.e., no fan rotation or no air flow). An interlock shall be provided to reduce transformer loading when cooling oil flow is not detected.

2. Over voltage and under voltage
   The transformer shall be protected from damage from any long-term over voltage or under voltage conditions that may exist. Protective settings and responses shall be documented.

3. Over temperature/Overpressure
   The transformer shall be provided with over temperature/overpressure annunciation and protection, including adequate fluid venting, removal of propulsion power, and remote indications. Protective settings and responses shall be documented and approved by Engineer. All over temperature conditions shall be logged by diagnostic system along with actual transformer temperatures.

4. Flow Detection and Protection
   The transformer shall be equipped with a flow detection device to ensure that there is adequate fluid flow. If low flow is detected, appropriate protective circuits shall protect the transformer.
and provide diagnostic warning and record. The protective scheme shall be submitted to the Engineer for approval. The flow device shall be protected from flying debris. Isolation valves shall be provided for flow detector removal.

Protection against fluid leaks and low fluid level shall also be provided.

Mechanical protection against debris strikes shall be provided for pumps, pipes, valves, heat exchangers and electrical bushings.

The Contractor shall provide description of entire protective scheme.

### 9.9.9.6 Tank

1. **Construction**
   The transformer tank shall be of sound, welded-steel construction. All cover plates and appurtenances shall be secured with elastic stop nuts where attached with bolts, or by an alternate method approved by the Engineer.

2. **Grit Blasting**
   Prior to assembly, tanks, including all welds, shall be grit blasted inside and out. The assembly shall be properly and thoroughly cleaned after grit blasting.

3. **Pressure**
   Each transformer tank shall be equipped with two pressure relief devices. Relief valves shall be located and arranged so as to preclude the possibility of escaping coolant contacting passengers or undercar apparatus. Interlocking from the overpressure devices shall be included in the MCB closing chain. A breakable disc device shall not be permitted.

4. **Fittings**
   Each transformer tank shall be complete with a drain valve, top filter press valve, sampling valve, and coolant fill pipe. The expansion space shall be provided with a manual bleed (vent) valve. The valves shall have plugs in the open ends and shall be clearly identified. All valves and fittings shall be protected from flying objects.

5. **Inductors**
   A. **Location:**
      Main and auxiliary filter inductors, if required, shall be provided within the main transformer tank and cooled by the transformer cooling system

   B. **Mounting**
      The transformer may be either resiliently or solidly mounted in or under the locomotive. However, in either case, its support shall be of adequate design causing minimum deflection or carbody vibration. It is permissible, at the Contractor’s option, for a resiliently mounted transformer to function, in conjunction with the design of the carbody structure, as a vibration damper. In any case, the transformer mounting design shall be presented to Engineer for approval.
9.9.9.7 Core and Coils

1. Core
   The transformer shall be of shell-type or core-type with limbs closed with yokes construction to give the best mechanical protection to the windings and shall be designed to eliminate the gap variations experienced in some types of core construction. Alternate construction types shall be subject to approval of the Engineer.

2. Coils
   The coils shall be copper, pancake or layer type windings, with large surface areas for the dissipation of heat. Ceramic button separators, or approved equal, shall be placed between the coils to absorb heat from the coil surfaces and dissipate the heat easily to the coolant stream between coils, thereby eliminating potential hot spots.

3. Bracing
   The coils shall be adequately braced, strengthened, and provided with sufficient spring packs at the ends of coil stacks to secure the coils to withstand without injury the effects of shocks and vibration during operation. This includes a hard coupling (5 mph). The coil shall also withstand thermal stresses as well as radial and axial pulsating forces due to the fluctuating pattern of the load current, system faults, and the presence of harmonics. The transformer shall withstand without injury short circuits across any or all of the low voltage taps with the highest primary voltage available. For design purposes, it shall be assumed that such short circuits shall occur over the 30-year transformer lifetime.

4. Details
   All flexible connectors shall be tied together to prevent spreading. All non-metallic nuts used shall be locked with epoxy cement. All current-carrying parts of the transformer and smoothing inductors shall be copper. All surfaces shall be designed to minimize corona effects.

5. Approval
   The entire core and coil design shall be subject to approval by Engineer.

9.9.9.8 Impedance and Magnetizing Current

1. Impedance
   The impedance of the transformer shall be sufficient to protect the unit from mechanical and thermal damage under short circuit conditions. The minimum transformer impedance shall be 20 percent using the primary winding kVA as a base and considering each winding to every other winding and all traction secondary windings in series. This must be met at all voltages and frequencies listed in Section 2.

2. Inrush
   The transformer magnetizing current shall be less than eight times the rated full load current under any operating conditions. The maximum inrush current must be less than 2500 Amps on the 25 Hz catenary supply voltage. The design calculations associated with this requirement shall be submitted for review and approval prior to transformer construction.
9.9.9.9 Electrical Connections

1. General
   All transformer connections shall be protected from flying objects by solid metal shroud(s).

2. Low-Voltage Bushings
   The primary return and low voltage bushings shall be of resin material, or approved equal.

3. High-Voltage Bushings
   The high-voltage termination(s) shall be approved deadfront separable connectors per IEEE STD 386-1995 with a minimum BIL of 150kV, as manufactured by Elastimold or equal. Acoustic testing shall be used to ensure insulators are discharge free before installation.

Removal and replacement methods must be straightforward and fool-proof. An easily maintainable design is required. The design shall be subject to approval by the Engineer.

9.9.9.10 Carbody Connection

The transformer primary return bushing shall be connected to the carbody and ground brushes. The connection shall use a drilled and tapped copper or bronze pad brazed to the underframe. Earth braid loss detection shall be included. All measures to stop catenary return through the journal bearing shall be taken.

9.9.9.11 Markings

1. General
   All nameplates, warning signs, and identification tags shall be manufactured of stainless steel, or approved alternate, with all information and data visibly stamped and shall be securely fastened to the transformer.

2. Transformer Nameplate
   The transformer shall have ratings, connection, diagrams, and other information stamped in accordance with IEEE C57.12.00-2000, Section 5.12, Nameplates. The nameplate shall be mechanically fastened to the transformer tank at an easily accessible location.

9.9.9.12 Tap Changer on Primary Windings

The main transformer shall incorporate a heavy-duty motorized tap changer of service-proven design to effect primary voltage transitions. External switching of the secondary windings is permitted.

The tap changer shall be designed to effect the primary voltage transition in the shortest time practicable.
The tap changer shall be designed to operate a minimum of 50 times a day, for the life of the transformer, with required periodic maintenance attention no more frequently than the remainder of the propulsion equipment. Tap changer shall be designed to only switch under no load current condition. The tap changer shall be externally accessible for maintenance without disturbing the transformer or requiring the removal of coolant.

SEPTA is willing to consider alternative designs that do not require a primary winding tap changer.

9.9.9.13 Current Transformer

The current transformer shall provide an output that is proportional to the main transformer primary current (pantograph current). This output shall be used by the propulsion control system for control and protective functions.

9.9.9.14 Voltage Transition

Appropriate switchgear, transformer windings, and controls shall be provided for transition between all voltage/frequency combinations. Transition shall be possible at any speed.

The Operator shall normally remove propulsion power via the Master Controller before traversing a phase break/dead section, but the design of switchgear, transformer windings, and controls shall not inherently require that he do so. Voltage transition shall be accomplished correctly even if the Operator fails to remove propulsion power before traversing a phase break/dead section.

The transition shall be completed in the minimum possible time. Indications of the transition shall be provided to the Operator through the CDS (Central Diagnostic System) and displayed on the TOD (Train Operator Display). Line voltage shall be prominently displayed on TOD.

9.9.9.15 Dead Sections (Phase Breaks)

Phase breaks (i.e., dead sections that have the same voltage on both sides) shall be treated as voltage transitions, normally the only difference being that the “new” voltage shall be the same as the “old” voltage. Dead sections can have 5000 volts or more voltage potential.

9.9.9.16 Wrong-Voltage Protection

The voltage transition controls shall incorporate appropriate protection to minimize damage and avoid incorrect operation in the event that the equipment inadvertently connects to the line when configured for the wrong line voltage. (MCB shall open with loss of voltage and not re-close until correct voltage and frequency are detected.)

9.9.9.17 Diagnostics

The voltage transition function shall have a Local Diagnostic and Test System (LDTS) as specified in Section 14. The LDTS may be incorporated within the CDS.
9.9.9.18 Primary Power Return

The primary power return shall have sufficient capacity to handle normal operating currents and fault currents. This includes the catenary wire contacting the car body resulting in the sub-station breaker to open.

9.9.10 FAULT CURRENT

Fault Current shall be designed with the following parameters:

- Maximum 40,000 A for 200 milliseconds
- More often at 30,000 A for 100 milliseconds

The primary power return shall be by means of ground brushes. The primary power return shall, in addition, meet the applicable requirements of APTA SS-E-005-98.

Primary power returns from individual apparatus, except the main transformer primary windings, shall be connected to a ground bus which shall be isolated from the carbody. The ground bus shall be connected to primary power return ground brushes on each axle of the locomotive (one primary power return ground brush per axle).

Primary power return ground brushes shall be distinct from safety ground brushes. Each axle shall have at least one primary ground brush assembly and at least two (separate) safety ground brush assembly.

Other than the main transformer primary windings, the carbody shall not be used as part of the primary power return from any equipment.

Each primary power return ground brush and its cable and connections shall be sized such that no ground brush normally carries a current, including both return current and shunted running rail current, in excess of one-half of its continuous current rating.

The Contractor shall submit, for approval, a complete power return scheme, which shall demonstrate compliance with the Technical Specification This shall include a fault current analysis.

9.9.10.1 Safety Grounding

All equipment on the vehicle shall be safety-grounded to the vehicle structure using ground pads meeting the requirements of Section 15.23.12.1. Safety grounding shall, in addition, meet the applicable requirements of APTA SS-E-005-98.

All equipment subject to motion with respect to the carbody and shock-mounted equipment shall be grounded with flexible, strap-type grounding leads bolted between the carbody grounding pad and the equipment’s grounding pad. Stranding shall be equivalent to, or better than, ICEA Class M.

Other than the main transformer primary windings, safety grounding shall be distinct from primary power return wiring.
Unless otherwise approved by the Engineer, grounding connections to the carbody and equipment shall be made through silver-plated or tinned copper pads of an adequate area, silver-soldered or brazed. Transition (base) plates, if used, shall be made from the same alloy group as the respective carbody and piece of equipment. The base plate shall be welded to the carbody or equipment.

Grounding connections shall not be made to aluminum alloy members.

All ground pads shall be visible and accessible for inspection and troubleshooting.

The ground connections shall be attached by a bolt, washer, and nut designed for the purpose and made of a material suited for this application.

Anti-corrosive, conductive grease, suitable for the materials used, shall be applied at the connection.

The vehicle structure and truck frames shall be grounded to all four axles on a locomotive through axle-mounted safety ground brushes (at least one safety ground brush per axle).

The grounding connection and termination method shall apply uniform pressure to the conductive surface, and the current density shall not exceed the bonding requirements given below.

All grounding and bonding jumpers and straps shall be sized to handle fault current and lightning discharge current, for which the voltage drop shall not exceed 25 volts. The bonding method employed shall not produce a dc resistance in excess of 0.0025 ohms, or more than 0.025 ohms at 150 kHz for any applied ac voltage.

The Contractor shall submit, for approval, a complete grounding scheme, which shall indicate by text and clear sketch(es) the means by which it is proposed to prevent currents from passing through journal, motor, and truck-center bearings; shall demonstrate compliance with Section 15.23.12.1; and shall demonstrate adequate rating to carry shunted running rail currents.

### 9.9.10.2 Ground Brushes and Brush Holders

Ground brushes shall be of a proven design in wide use in the railway industry. The ground brushes shall, in addition, meet the applicable requirements of APTA RP-E-002-98.

Ground brushes shall bear on a bronze ground ring. Carbody grounding and power return brushes may be arranged to contact the same axle ground brush ring. The ground ring shall have a wear life not less than the overhaul interval of other wheel set components.

Brushes shall be made from metal graphite. Brush leads shall project from the top of the brush with no possibility of brush leads impeding brush travel before the brush is fully worn. Each brush shall be delivered with the working face profiled to match the ground ring radius. The brush shall be keyed or otherwise designed in such a way that installation in an incorrect orientation is precluded. The brush shall have a molded-in or machined-in wear indicator providing a direct visual indication that the brush has insufficient wear life remaining to continue in service until its next scheduled inspection. All brushes (both carbody grounding and power return) shall be identical.
Power return ground brush holders shall be electrically insulated from carbody and truck equipment and shall be electrically connected only to the ground bus described in Section 15.23.12.1. Power return ground brush holder insulation shall be rated to withstand the maximum sustained line voltage of Section 2.2.8.1, in order to avoid energizing of the carbody or truck in the event that primary power is inadvertently applied in the absence of ground brushes.

Carbody grounding brush holders shall be electrically insulated from carbody and truck equipment in a manner consistent with the approved grounding scheme.

Each ground brush holder shall be readily accessible from under or side of the locomotive for maintenance and shall be arranged for inspection and brush replacement by a single worker. Each ground brush holder shall be internally arranged to preclude entanglement between brush leads and other internal components, especially brush springs. Each brush spring shall be captive to the ground brush holder cover. All exposed components in the interior of the ground brush holder shall be at the same electrical potential. All ground brush holder details that require disassembly or removal in the course of inspection or brush replacement, including but not limited to covers, springs, and electrical connections, shall be identical for all ground brush holders (both carbody grounding and power return).

All ground brushes (both carbody grounding and power return) shall have a wear life of at least one year, based on an inspection interval of not less than 92 days.

The ground circuits, for both primary power return and safety grounding, including wires, brushes, and wheels, shall be sized so that each brush circuit can independently carry the maximum fault current, without damage, while limiting the voltage difference between the carbody or return bus and the running rail to 20 volts.

9.10 MONITORING and DIAGNOSTICS

Each device in Section 9 shall communicate to the diagnostics system per Section and record all data and events as described in Section 14.

These events and data shall originate from discrete sensors.

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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>[ \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>[ \frac{0.4 + 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>

**Carbody Accelerations**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Passenger Cars</th>
<th>Other Vehicles</th>
<th>Requirements</th>
</tr>
</thead>
</table>
| Carbody Lateral (Transient) | ≤ 0.65g peak-to-peak 1 sec window excludes peaks < 50 msec | ≤ 0.75g peak-to-peak 1 sec window 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
<table>
<thead>
<tr>
<th>Carbody Lateral (Sustained Oscillatory)</th>
<th>≤ 0.10g RMS&lt;sup&gt;4&lt;/sup&gt; 4 sec window&lt;sup&gt;4&lt;/sup&gt; 4 sec sustained</th>
<th>≤ 0.12g RMS&lt;sup&gt;4&lt;/sup&gt; 4 sec window&lt;sup&gt;4&lt;/sup&gt; 4 sec sustained</th>
</tr>
</thead>
<tbody>
<tr>
<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>
<td></td>
<td></td>
</tr>
<tr>
<td>Carbody Vertical (Transient)</td>
<td>≤ 1.0g peak-to-peak 1 sec window&lt;sup&gt;3&lt;/sup&gt; excludes peaks &lt; 50 msec</td>
<td>≤ 1.25g peak-to-peak 1 sec window&lt;sup&gt;3&lt;/sup&gt; excludes peaks &lt; 50 msec</td>
</tr>
<tr>
<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>
<td></td>
<td></td>
</tr>
<tr>
<td>Carbody Vertical (Sustained Oscillatory)</td>
<td>≤ 0.25g RMS&lt;sup&gt;4&lt;/sup&gt; 4 sec window&lt;sup&gt;4&lt;/sup&gt; 4 sec sustained</td>
<td>≤ 0.25g RMS&lt;sup&gt;4&lt;/sup&gt; 4 sec window&lt;sup&gt;4&lt;/sup&gt; 4 sec sustained</td>
</tr>
<tr>
<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>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Truck Lateral Acceleration<sup>5</sup>**

<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 RMS&lt;sup&gt;4&lt;/sup&gt; 4 sec window 2 sec sustained</td>
<td>2 sec window 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>

<sup>1</sup> 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.

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

<sup>3</sup> 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.

<sup>4</sup> RMS<sub>L</sub> = RMS with linear trend removed.

<sup>5</sup> 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 (i.e., 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 ½ 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 A710, 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>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Truck Vertical</td>
<td>100% ready to run car body (total) weight</td>
</tr>
<tr>
<td>Lateral</td>
<td>25% x Vertical</td>
</tr>
<tr>
<td>Longitudinal</td>
<td>25% x Vertical</td>
</tr>
<tr>
<td>Tread Brake and Disc Brake Units</td>
<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>Motor and Gear Unit</td>
<td>Maximum applied loads due to short circuit torque in the motors</td>
</tr>
<tr>
<td>Dampers</td>
<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.

<table>
<thead>
<tr>
<th>Fatigue Test Loads</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Truck frame (and bolster, if applicable)</strong></td>
</tr>
<tr>
<td>Vertical (Range)</td>
</tr>
<tr>
<td>Lateral (Range)</td>
</tr>
<tr>
<td>Longitudinal (Range)</td>
</tr>
<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><strong>Motor and Gear Unit</strong></td>
</tr>
<tr>
<td>Horizontal (Range)</td>
</tr>
<tr>
<td>Vertical (Range)</td>
</tr>
<tr>
<td>Dampers (Amplitude)</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 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   FRICTION 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 FRICTION 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 retainment 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.

END OF SECTION
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12 AUTOMATIC TRAIN CONTROL/POSITIVE TRAIN CONTROL AND EVENT RECORDER SYSTEMS

12.1 EQUIPMENT REQUIREMENTS

Due to FRA mandated rules and regulations and the safety critical nature of the ATC/PTC system, the Contractor shall supply equipment that is identical to SEPTA’s current ATC/PTC system. Listed below is the part numbers of the Ansaldo STS (ASTS) ATC/PTC system as used by SEPTA:

<table>
<thead>
<tr>
<th>Part Number</th>
<th>Description</th>
<th>Vendor</th>
</tr>
</thead>
<tbody>
<tr>
<td>MCP-System-3</td>
<td>Complete Mobile Communications Package:</td>
<td>STI-CO</td>
</tr>
<tr>
<td>MCP-SEPTA</td>
<td>Mobile Communication Package including Digi Modem, Power-One Power Supply, GE PTC Radio, Filters, and Cabling</td>
<td>STI-CO</td>
</tr>
<tr>
<td>MCP-PWR</td>
<td>Optional External Power and Serial Bracket</td>
<td>STI-CO</td>
</tr>
<tr>
<td>HDLP-MB-PLL25-SEPTA</td>
<td>Antenna System, SEPTA Configuration PTC/CEL/CEL/Wi-Fi</td>
<td>STI-CO</td>
</tr>
<tr>
<td>HDLP-GPS</td>
<td>Optional GPS Sensor for Antenna System</td>
<td>STI-CO</td>
</tr>
<tr>
<td>HDLP-RDM</td>
<td>Optional Radome for SEPTA Antenna System</td>
<td>STI-CO</td>
</tr>
<tr>
<td>PKIT-LMR-240-UF-FR-SEPTA</td>
<td>Cable Kit Antenna to MCP, SEPTA Configuration, Fire Rated</td>
<td>STI-CO</td>
</tr>
<tr>
<td>370-3100-ant-sep</td>
<td>Roadway Worker Alert Systems (RWAS) Antenna Assembly</td>
<td>ProTran</td>
</tr>
<tr>
<td>370-3100ND-SEP</td>
<td>Vehicle Mounted Controller</td>
<td>ProTran</td>
</tr>
<tr>
<td>D604218-A01</td>
<td>ATC/PTC Kit for Electric locomotive</td>
<td>Siemens</td>
</tr>
<tr>
<td>C070G230</td>
<td>CTV Cable</td>
<td>Siemens</td>
</tr>
<tr>
<td>C070G293R2</td>
<td>CTV Coax Cable</td>
<td>Siemens</td>
</tr>
<tr>
<td>C070G294R2</td>
<td>CTV Twin Axial Cable</td>
<td>Siemens</td>
</tr>
<tr>
<td>D5664H61R0</td>
<td>Vehicle ID Module</td>
<td>Siemens</td>
</tr>
<tr>
<td>2RBS2A1</td>
<td>RedBOX Star Event Recorder</td>
<td>Deuta Werke</td>
</tr>
</tbody>
</table>

The above supplied ATC/PTC equipment shall meet all functional requirements as outlined in the Ansaldo PTC System Functional Description document number S820661-01300-2100 latest revision.

As part of this contract, the Contractor shall also provide to SEPTA upgraded vehicle software for each ATC/PTC, MCP and event recorder systems. SEPTA will at its discretion install the upgraded software on all legacy ASTS equipment. The new software supplied shall be designed such that all Contractor supplied ATC/PTC, MCP and Event Recorder System (ERS) components are interchangeable with SEPTA’s existing ATC/PTC devices.
### 12.2 GENERAL SYSTEM DESCRIPTION

The Automatic Train Control (ATC) and Positive Train Control (PTC) systems shall enforce the safe operation of the train primarily through forced acknowledgement and overspeed protection. Each system can initiate a penalty brake application in order to stop the train if the operator is unable or unwilling to do so.

The combined equipment provides the function of traditional cab signal and modern Positive Train Control (PTC) with Civil Speed Enforcement. The cab signal portion is based on an NORAC 9-aspect system with overspeed protection. The PTC portion shall be a SEPTA PTC system which will provides the Civil Speed Enforcement. The ATC/PTC equipment is designed for use on SEPTA property and is compatible with NEC / Amtrak operation. It shall be designed utilizing fail-safe techniques to provide a vital platform that can be relied upon to perform safety-critical functions.

The ATC equipment uses track receivers to continuously monitor coded carrier signal in the rail. Coded carrier information is translated to signal aspect information, which is used for traffic control.

The PTC equipment is a transponder-based system that enforces civil speed restrictions for fixed locations such as curves, bridges, stations, etc. as well as temporary speed restrictions and Positive Train Stop. While cab signal equipment enforces vehicle operation based on speed and time; the PTC equipment enforces operation based on speed and distance (position).

A single ATC/PTC system shall be located on-board. User input to the system shall come from devices within the operator’s cab. Normally input can only be produced from an activated cab, which occurs when the cab is made up as the lead locomotive in the consist. In order to accomplish its control tasks, the equipment interacts with other systems on the vehicle, such as the air brake, diagnostic and the vehicle control systems.

The ATC/PTC system shall have an integrated alerter system which shall be responsible for monitoring the train operator vigilance. The ATC/PTC system shall interface with a FRA compliant stand alone event recorder. All FRA required ATC and PTC system inputs, outputs and messages will be communicated and stored within the event recorder.

The ATC and PTC equipment shall be installed at an accessible location in each locomotive. The equipment of each of these systems shall be designed to be packaged in one equipment cubicle. The equipment enclosure shall be fitted with a restricted access key lock. The key to unlock this enclosure shall be an Illinois Lock Co. model G341 key.

The Contractor shall supply all necessary auxiliary devices, pressure transducers/switches, cutouts, brake system interfaces, etc., to provide a complete functional system.

### 12.3 ATC/PTC System Requirements

The ATC/PTC system shall abide by all FRA rules and regulations and conform to all Northeast Operating Rules Advisory Committee (NORAC) rules and regulations. As part of the system design, either ATC or
PTC will be capable of operation as an individual system. If the ATC system is cutout, the PTC system shall stay active. If the PTC system is cutout, the ATC system shall stay active.

The ATC system shall perform the following functions:

- Vitally detect, at all times, block signal information transmitted from the running rail into the active cab of the train, and shall enforce the speed limits associated with the signal information received.
- Measure vehicle speed using a dedicated speed sensor.
- Incorporate two (2) Aspect Display Units (ADU).
- Perform ATC protection in the form of forced acknowledgement in response to signal aspect downgrades.
- Allow operation in non-cab signaled territory at speeds up to 79 MPH.
- Enforce a Positive Train Stop (PTS) as defined by the SEPTA PTC system.
- Perform an automated departure test when activated by the ADU keyswitch. This onboard test feature shall be capable of testing the cab signal, ATC and alerter systems. The cab signal test function shall operate in the presence of 25 Hz traction power, constant or sporadic 100 Hz and/or 250 Hz carrier, and with a valid cab signal (coded 100 Hz with or without 250 Hz) coded rate within the rails.
- Report all FRA and SEPTA specified real-time data to an external FRA-compliant Event Recorder.
- Record system operation within an internal data logger. Access to this information shall be available by Portable Test Equipment (PTE), the MCP Wi-Fi function or over locomotive’s cellular network.
- Perform real-time event monitoring. Access to this information shall be available by Portable Test Equipment (PTE) or the MCP Wi-Fi function or over locomotive’s cellular network.

The PTC system shall perform the following functions:

- Acquire wayside transponder data and translate it into civil speed restrictions.
- Acquire wayside signal / route data and translate it into civil speed restrictions.
- Acquire Temporary Speed Restriction (TSR) package data and apply corresponding speed restrictions.
- Measure vehicle speed and distance traveled using a dedicated speed sensor.
- Automatically compensate for wheel wear. The ATC system shall receive and incorporate the updated wheel diameter in all speed calculations.
- Report Maximum Authorized Speed (MAS), vehicle speed, and PTC operating status to the operator via the ADU.
- Enforce Civil speed requirements as required by the Onboard Computer (OBC).
- Enforce Positive Train Stop (PTS) as defined by the PTC system.
• When activated by the ADU keyswitch, perform an automated on-board departure test. This onboard test feature shall be capable of testing the PTC system including transponder antenna, MCP and OBC. The cab signal test function shall operate in the presence of 25 Hz traction power, constant or sporadic 100 Hz and/or 250 Hz carrier, or with a valid cab signal (coded 100 Hz with or without 250 Hz) coded rate within the rails.

• Report real-time data to an external FRA-compliant Event Recorder.

• Record system operation within an Internal data logger. Access to this information shall be available by Portable Test Equipment (PTE), Wi-Fi or over locomotive’s cellular network.

• Perform real-time event monitoring. Access to this information shall be available by Portable Test Equipment (PTE), Wi-Fi or over locomotive’s cellular network.

### 12.4 ATC System Operation

#### 12.4.1 Cab Signal Decoding

Cab signal aspect information is communicated to a vehicle using coded carrier signals in the rail. The on-board cab signal equipment inductively receives this information through track receiver antennas mounted over the rails, ahead of the lead axle.

The SEPTA ATC system uses dual carrier frequencies (100 and 250 Hz) modulated to represent unique signal aspects. The signal aspect enforced by the on-board cab signal equipment is derived from the decoded carrier signals received. In dual-carrier operation (100Hz and 250Hz), either only the modulated 100Hz carrier is utilized in the rail, or both the 100Hz and 250Hz carriers are used. When both carriers are used, the 250Hz signal is present only during the off time of the 100Hz signal.

#### 12.4.2 Aspects, Indications, and Authorized Speeds – NEC

Listed below are the carrier code rates, aspects, and permitted speeds:

<table>
<thead>
<tr>
<th>F1 Code Rate (91.67/100Hz)</th>
<th>F2 Code Rate (250Hz)</th>
<th>Cab Signal Aspect</th>
<th>Speed Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>180</td>
<td>180</td>
<td>Clear</td>
<td>100 MPH/MAS</td>
</tr>
<tr>
<td>180</td>
<td>No Code</td>
<td>Clear</td>
<td>100 MPH/MAS</td>
</tr>
<tr>
<td>270</td>
<td>270</td>
<td>Clear</td>
<td>100 MPH/MAS</td>
</tr>
<tr>
<td>120</td>
<td>120</td>
<td>Cab Speed 80</td>
<td>80 MPH</td>
</tr>
<tr>
<td>270</td>
<td>No Code</td>
<td>Cab Speed 60</td>
<td>60 MPH</td>
</tr>
<tr>
<td>120</td>
<td>No Code</td>
<td>Approach Medium</td>
<td>45 MPH</td>
</tr>
<tr>
<td>75</td>
<td>75</td>
<td>Approach</td>
<td>30 MPH</td>
</tr>
<tr>
<td>75</td>
<td>No Code</td>
<td>Approach</td>
<td>30 MPH</td>
</tr>
<tr>
<td>No Code</td>
<td>No Code</td>
<td>Restricted</td>
<td>20 MPH</td>
</tr>
<tr>
<td>No Code</td>
<td>No Code</td>
<td>Non-Cab Signal Territory</td>
<td>79 MPH</td>
</tr>
</tbody>
</table>
12.4.3 Departure Test Required Mode
When the power is removed from the ATC system, the system will restart in a Departure Test Required mode. This mode shall stay active until a departure test has been completed successfully. While in departure test required mode, all cab signal aspect displays are dark. The system shall enforce a 10 mph speed limit while in this mode. The ADU shall display a “ATC, DEPT TEST REQD” message while in this mode. A bypass switch shall be provided within the equipment enclosure. To initiate a bypass, the switch must be pressed each time after the equipment is reset or powered-up.

12.4.4 Speed Sensing Requirements
Vehicle speed shall be measured using axle alternators. The configured vehicle type and wheel size data shall be incorporated within the vehicle I.D module for use by the ATC/PTC systems.

12.4.5 Non-Cab Signal Territory
Provision shall be made to permit operation in territory without cab signals. When an input is provided to the cab signal/speed control system indicating entry to non-cab signal territory, the system shall darken all cab signal aspects, deactivate acknowledgment circuits and impose a 79 mph speed limit. The input shall be manual from a SEPTA approved Non-Cab Signal territory button/switch in the cab.

Upon entering cab signal equipped coded territory, any code received shall cancel the Non-Cab Signal Territory condition and cause the cab signal to be displayed. At this time it shall be necessary to acknowledge the change in operating mode. The 79 mph speed limit shall be removed and the speed limit shall be as determined by the cab signal.

12.4.6 Signal Carriers
The cab signal equipment shall operate using two carrier frequencies: F-1, a nominal 100 Hz and F-2, a nominal 250 Hz.

Operation shall be such that the equipment shall interpret the F-1 carrier as specific speed commands for each coding rate and shall interpret the same F-1 coding rates as separate and distinct higher speed commands when the F-2 carrier is present during the "off" coding periods of the F-1 carrier.

The cab signal equipment shall respond to and operate successfully with the following carrier frequencies and tolerances:

- F-1 100 Hz 90 Hz to 102 Hz
- F-2 250 Hz 247 Hz to 253 Hz

The minimum in-rail coded carrier current over which the cab signal equipment shall successfully operate are:

- F-1 2.0 amperes
- F-2 1.25 amperes
The calibration point is 1.65 amps for F1 and 0.9 amps for F2.

The system shall be arranged to provide an indication to the ATC/PTC data logger and LDMS if the in-rail coded carrier current is sensed to be more than 20 amperes or less than the minimum tolerances for F-1 or F-2. The cab signal from the pick up bars shall be monitored and recorded for current level, code and carrier frequency. The geographic location, when available and time shall also be indicated within the recorded event.

The cab signal equipment installed on the locomotive will operate in Amtrak and SEPTA territories. As such the equipment shall be capable of operating in the presence of up to 0.5 amperes of in-band noise for the 91.67 Hz/100 Hz system and up to 0.25 amperes for the 250 Hz system, as defined on the Amtrak EMI Limit curve A-60-7659.

12.4.7 Codes

The cab signal/ATC equipment shall respond to and operate successfully within the following tolerances:

<table>
<thead>
<tr>
<th>Signal</th>
<th>Operating Range</th>
<th>Signal Recognition</th>
</tr>
</thead>
<tbody>
<tr>
<td>250 Hertz carrier</td>
<td>247Hz - 253Hz</td>
<td></td>
</tr>
<tr>
<td>91.67/100 Hertz carrier</td>
<td>90Hz to 102Hz</td>
<td></td>
</tr>
<tr>
<td>270 Code Rate</td>
<td>268 - 283 CPM</td>
<td>11 half cycles</td>
</tr>
<tr>
<td>180 Code Rate</td>
<td>178-188 CPM</td>
<td>6 half cycles</td>
</tr>
<tr>
<td>120 Code Rate</td>
<td>118-125 CPM</td>
<td>4 half cycles</td>
</tr>
<tr>
<td>75 Code Rate</td>
<td>71-77 CPM</td>
<td>3 half cycles</td>
</tr>
<tr>
<td>Cab Signal Aspect</td>
<td>3.2 seconds</td>
<td></td>
</tr>
<tr>
<td>Hold Time</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Code Rate Duty Cycle [worst case]</td>
<td>75/25</td>
<td></td>
</tr>
<tr>
<td>Onboard Equipment Minimum Rail Current Detection</td>
<td>1.65 ± 0.15 Amps (91.66/100 Hz) 0.9 ± 0.1 Amps (250 Hz)</td>
<td></td>
</tr>
</tbody>
</table>

The OBC shall be designed such that it is possible to adjust the F1 and F2 threshold values manually.

12.4.8 Power Supply

The ATC & PTC equipment shall each be powered by an isolated power supplies. Each power supply shall provide complete isolation from each other along with isolations from all vehicle circuits. If either the ATC or PTC power supply enters a fault condition, the non-faulted system shall continue to operate.

The locomotive battery system shall be designed to be floating from ground. The ATC/PTC system shall be totally independent of positive, negative, or combined battery ground faults.

12.4.9 Track Receivers

With new wheels installed on locomotive the track receivers shall be mounted 6.5” from top of rail. The track receivers shall have a minimum height adjustment of .5” increments over a 4 inch range.
12.4.10 Aspect Display Unit (ADU)

An Aspect Display Unit shall be fitted in each cab. The ADU shall incorporate a photosensitive device that senses ambient light intensity. Utilizing this sensor, the ADU display intensity shall be automatically adjusted to compensate for changes in the ambient light. In order to override this feature, the ADU shall contain a pushbutton switch that will manually control the auto dimming feature of the ADU. The manual mode of adjustment will remain in effect until the time the unit is no longer the controlling locomotive. The ADU shall default to automatic brightness control each time the locomotive cab is activated.

The SEPTA ADU is pictured along with a brief description of the respective ADU functions: The table below describes the ADU front view functional items:
<table>
<thead>
<tr>
<th>Item</th>
<th>Function</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>MOVEMENT AUTHORITY</td>
<td>This is a 2 row X 8 character alphanumeric display and a two (2) square LED signal indicators. The 2 square LED signal indicator shall be capable of a Green, Yellow and Red Display. These 2 square LEDs shall display the NORAC certified cab signal aspect. The 2 row X 8 character display is a green LED dot matrix device with an overall character height of at least 7mm. The LED based display shall indicates the cab signal aspects and worded according to NORAC Rules. This includes a positive stop aspect indication from PTC.</td>
</tr>
<tr>
<td>2</td>
<td>MAXIMUM AUTHORIZED SPEED</td>
<td>This is a red LED display that indicates the maximum authorized vehicle speed (MAS). This will be the lower of the maximum authorized speed permitted by the ATC or PTC system, with the governing system being indicated by LEDs to the left side (ATC) or right side (PTC) of the MAS display. This speed indication shall track the brake warning curve enforced by the PTC system.</td>
</tr>
<tr>
<td>3</td>
<td>ACTUAL SPEED</td>
<td>This is a red LED display that indicates the actual vehicle speed.</td>
</tr>
<tr>
<td>4</td>
<td>ATC</td>
<td>This is a yellow LED that when lit indicates that the ATC system is generating an MAS lower than the PTC system. If there is currently a penalty associated with the ATC system, this LED will flash.</td>
</tr>
<tr>
<td>5</td>
<td>PTC</td>
<td>This is a yellow LED that when lit indicates that the PTC system is generating an MAS lower than the ATC system. If there is a penalty currently associated with the PTC system, this LED will flash.</td>
</tr>
<tr>
<td>6</td>
<td>OVERSPEED</td>
<td>This is a yellow indicator, that when lit, indicates that the vehicle speed is in excess of either the ATC MAS or the PTC MAS.</td>
</tr>
<tr>
<td>7</td>
<td>NO VALID TSR DATA</td>
<td>This is a red LED that when illuminated indicates that there is no valid temporary speed restriction (TSR) data. This is typically caused by the PTC transponder or the data radio not picking up correct TSR messages. Under this condition, the MAS display will indicate “--”.</td>
</tr>
<tr>
<td>8</td>
<td>ATC CUT-IN</td>
<td>This is a green LED, that when illuminated indicates that the ATC system is cut in and operational.</td>
</tr>
<tr>
<td>9</td>
<td>PTC CUT-IN</td>
<td>This is a green LED, that when illuminated indicates that the PTC system is cut in and operational.</td>
</tr>
<tr>
<td>10</td>
<td>ATC CUT-OUT</td>
<td>This is a yellow LED, that when illuminated indicates that the ATC system is cut out.</td>
</tr>
<tr>
<td>11</td>
<td>PTC CUT-OUT</td>
<td>This is a yellow LED, that when illuminated indicates that the PTC system is cut out.</td>
</tr>
<tr>
<td>12</td>
<td>ATC FAILURE</td>
<td>This is a red LED that when illuminated indicates that there is a failure in the ATC system. This is an indication that the Train Engineer should manually cut out the ATC system, and subsequently follow all relevant operational rules.</td>
</tr>
</tbody>
</table>
### Item Function Description

<table>
<thead>
<tr>
<th>Item</th>
<th>Function</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>13</td>
<td>PTC FAILURE</td>
<td>This is a red LED that when illuminated indicates that there is a failure in the PTC system. This is an indication that the Train Engineer should manually cut out the ATC system, and subsequently follow all relevant operational rules.</td>
</tr>
<tr>
<td>14</td>
<td>ERS FAILURE</td>
<td>This is a red LED that when illuminated indicates that there is a failure in the event recorder system (ERS).</td>
</tr>
<tr>
<td>15</td>
<td>VALID DATABASE</td>
<td>This is a green LED, that when illuminated indicates that a valid database has been uploaded from the PTC transponder.</td>
</tr>
<tr>
<td>16</td>
<td>SUPPRESSION</td>
<td>This is a yellow LED, that when illuminated indicates that the brake system is in suppression.</td>
</tr>
<tr>
<td>17</td>
<td>[SPARE]</td>
<td>This is a SPARE orange LED.</td>
</tr>
<tr>
<td>18</td>
<td>MESSAGES</td>
<td>This is a textual display that is used to pass messages to the Train Engineer. These messages are related to PTC and ATC departure test, TSR Messages, fault annunciation, NON-CAB SIGNAL TERRITORY operation and ADU indicator DIMMING Mode control.</td>
</tr>
<tr>
<td>19</td>
<td>MESSAGE SELECT</td>
<td>This is a pushbutton switch that is used in conjunction with the message display. The Train Engineer can also select indication illumination intensity using this switch.</td>
</tr>
<tr>
<td>20</td>
<td>ALERTER</td>
<td>This is red LED that is caused to flash by the alerter (vigilance) system.</td>
</tr>
<tr>
<td>21</td>
<td>ATC/ALERTER SONALERT</td>
<td>This is a dual tone alarm. One tone shall sound when the alerter system reaches a time-out. A different tone shall sound when the ATC system annunciates an overspeed condition or downward code change.</td>
</tr>
<tr>
<td>22</td>
<td>PTC SONALERT</td>
<td>This is a single tone alarm that sounds when the PTC system annunciates an overspeed.</td>
</tr>
<tr>
<td>23</td>
<td>‘C’ SIGNAL</td>
<td>This is a lunar white LED that when illuminated indicates that ATC is cut out, and that there is no wayside cab signal present, and PTC is providing authority via the data radio to proceed to the next home signal.</td>
</tr>
<tr>
<td>24/25</td>
<td>PTC/ ATC DEPARTURE TEST</td>
<td>This is a key switch that when rotated 90° clockwise initiates a PTC or ATC departure test.</td>
</tr>
<tr>
<td>26</td>
<td>BRIGHTNESS</td>
<td>This is a pushbutton switch that overrides the auto dimming feature of the ADU. It is used to control the brightness of the display. Repeated pushing of the button shall cycle the brightness of the display through 5 different brightness levels. All brightness levels shall be approved by SEPTA.</td>
</tr>
</tbody>
</table>

### 12.5 DEPARTURE TEST

A departure test is a sequence of cab test functions that are performed to verify the operational integrity of the equipment as well as external control devices and operator controls and indicators. The provided ATC/PTC system shall include provision for separate ATC and PTC departure tests that are
sufficient in scope and design so as to meet all FRA requirements. As part of the departure test, the system shall verify communication with the odometer and LDMS.

In order to initiate a departure test, the operator shall first move the ADU keyswitch in the PTC or ATC direction. If all pre-requisite entry conditions are met, the departure test will proceed. If the pre-requisite entry conditions are not satisfied, the ADU will display the fault condition to the operator.

In order to perform a departure test, the following pre-requisite conditions are required:

- Parking brake is applied;
- The no motion indication is present;
- Cab signal territory is selected;
- The Brake Pipe is at least 90 psi;
- An air brake application of Suppression or greater is present; and
- A Forward or Reverse command is active

If a fault is detected during the operation of either departure tests, the ATC/PTC system shall display the fault condition to the operator on the ADU and record the fault within the LDMS.

### 12.6 EQUIPMENT HARDWARE AND LABELING

Visual indications, such as LED lamps, shall demonstrate that the system is functioning properly; similarly, failure and diagnostic indications shall be provided. Indications shall isolate a failure to a particular function, or to the interface between two functions.

Inputs for the equipment shall be de-bounced and shall be electrically isolated from one another. A visual indication, such as an LED lamp, shall be provided on the input board to each input to indicate when the input is activated.

Vital outputs for the equipment shall be electrically and physically isolated from one another. A visual indication, such as an LED lamp, shall be provided on the input board to each input to indicate when the output is activated.

Labels shall be provided by each input and output indication which clearly denote the respective function of each for ease of maintenance and troubleshooting.

### 12.7 MODULAR DESIGN

Modular design of components shall be incorporated to the maximum practical extent. Components or subassemblies with discrete function shall be plug-in modules and shall be labeled for ready identification. The circuit board rack shall be easily and quickly removed and replaced as a unit and shall
be designed for handling. Plug connectors shall be of rugged design suitable for the safety related circuits involved. Positive retention of plug-in modules shall be provided. Functionally interchangeable modules shall be physically interchangeable and those that are not functionally interchangeable shall be provided with positive means to prohibit physical interchangeability. The design shall be such that failure to install a module shall cause a more restrictive than normal system operation.

12.8 ENVIRONMENTAL CHARACTERISTICS

At a minimum, all electronic apparatus shall be designed and tested in accordance with IEEE 16, and all of the referenced standards contained therein. This includes, but is not limited to, operating/storage temperature environment, EMC and shock & vibration. Any variation from these requirements shall be submitted to the SEPTA Project Manager for review and approval.

12.9 ALERTER SYSTEM

The contractor shall provide a FRA mandated Alerter within the ATC/PTC system. The alerter shall be an OBC based system that is designed to enhance the safe operation of the locomotive by monitoring the alertness of the engineer. The system shall continuously monitor the actions taken by the engineer. In the absence of the detectable movement of the engineer in the specified time period, the alerter system notify the engineer by means of Overspeed light located on the ADU. The visual Overspeed light shall flash at a predetermined rate for 10 seconds. After 4 seconds in the visual alarm cycle, a second, audio alarm located within the ADU will activate. Failure to acknowledge the two alarms within the allotted time (10 seconds) shall result in a penalty brake application.

The alerter system shall activate the alarm sequence whenever any one of the following conditions occur:

- No monitored input has changed within 30 seconds with a Restrictive Aspect present.
- No monitored input has changed within 30 seconds in non-cab signal territory mode.
- No monitored input has changed within 30 seconds when either ATC or PTC is in the CUTOUT mode.
- No monitored input has changed within 30 seconds in “Departure Test Required” mode.
- The alerter while in cab signal territory shall, with an aspect greater than Restricting, activate the alarm sequence when no monitored input changes within (2400 ÷ train speed) seconds.

The following operator actions shall reset the alerter function and deactivate an alarm sequence:

- Activating the Horn
- Moving the Reverser handle
- Activating the ATC/PTC acknowledgement switch
• Brake cylinder bail off.
• Moving the Throttle handle
• Ringing the bell

The alerter shall become inactive and the timing cycle shall reset when any one of the following conditions are present:

• The cab is deactivated
• The parking brake is applied
• A Brake cylinder application of 25 psi or greater is present
• The Brake Pipe is at 0 psi
• The speed is at 0 mph

12.10 ODOMETER

A new cumulative mileage odometer with a visual display shall be installed in all locomotives. The odometer display shall utilize ATC/PTC system data for display. The information shall be displayed and recorded to the nearest mile.

12.11 ROADWAY WORKER ALERT SYSTEM

A Roadway Worker Alert System (RWAS) as manufactured by ProTran, Inc., shall be installed at each cab end of the locomotive. The operation and configuration of the RWAS shall be identical to SEPTA’s current RWAS system.

12.12 EVENT RECORDER SYSTEM

The Event Recorder shall be a ASTS PTC Deuta Werke Redbox Star Type 3AW Event Recorder, Deuta Werke part number 2RBS2A1. All FRA required ATC and PTC system inputs, outputs and messages will be communicated and stored within the event recorder. Access to Event Recorder data shall be available by Portable Test Equipment (PTE), the MCP Wi-Fi feature and over the locomotive’s cellular network.

The Event Recorder shall provide all functions necessary to comply with the requirements in the Code of Federal Regulations (CFR), Title 49, Parts 218 and 229 as published in the Federal Register. In addition to the data elements listed in Title 49 CFR section 229.135 SEPTA shall have the option of adding additional data elements. The final ERS configuration, including additional SEPTA specified events and sampling rate shall be subject to approval by SEPTA during periodic design reviews of these systems. The event
recorder shall be designed to meet all self-monitoring event recorder requirements as described in Title 49 CFR 229.

### 12.12.1 Vehicle Configuration

The event recorder shall determine which type of vehicle it is installed based on the vehicle number sent by the SEPTA PTC system to the event recorder over the RS422 interface. The Contractor shall be responsible for creating a new vehicle configuration for this contract and shall be responsible for the supply of revised software to SEPTA.

### 12.12.2 Time Management

The ERS time shall come from the MCP (Mobile Communications Package). When the time is not available from the MCP, the event recorder shall utilize its internal clock until time is received. The real time clock shall be buffered by a super capacitor which shall last a minimum of 10 days.

### 12.12.3 Digital Inputs

There shall be a total of 35 digital inputs. The digital inputs shall be checked every 20ms and a change shall be validated after 40ms.

### 12.12.4 Analog Inputs

There shall be a total of 8 analog inputs. 6 analog inputs shall be 4-20mA, 1 analog input shall be 0-10V and 1 analog input shall be -5V to 5V.

### 12.12.5 Download Log

- **Wireless**
  - The log shall be able to be downloaded wirelessly via the MCP Wi-Fi feature

- **Ethernet Connection**
  - The log shall be able to be downloaded with a laptop directly connected to the Ethernet service interface X13 on the recorder.

- **USB Flash Drive**
  - Standard USB flash drive download the last 48 hours.
  - Deu-Werk playback software configured USB flash drive

Depending on the user selected configuration, the following will be available for download:

- All data;
- All new data (From last download); or
- Most recent 48 hours of operation.

For all downloads, the status of download process shall be indicated. All event recorder download ports shall be easily accessible from the locomotive cab.
12.12.6 ERS 92 Day Activity Check

The event recorder shall have internal software designed to check for activity of each FRA required input. Each FRA required input shall change a minimum of once during the 92 day period. A failure of an input to change state of a 92 day period shall display an event recorder fault status on the ADU. The Contractor shall identify signals which are likely to not change over 92-days, and suggest the activity check on these inputs not be used.

12.12.7 ERS FRA Inspection Report

The event recorder playback software shall be capable of producing an FRA INSPECTION REPORT generated by the push of a button. The inspection report shall provide the date, car number and activity of each FRA required input for the last 48 hours of operation. This inspection report shall be able to be saved electronically and/or printed for SEPTA’s records.

12.12.8 ERS-LDMS Interface

The event recorder shall be monitored and accessed through the LDMS. The LDMS fault monitoring shall capture the event recorder data as it occurs and provide full data recording, security, and downloading capability.

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13 COMMUNICATIONS

13.1 GENERAL

The locomotive’s configuration shall contain a two-way radio and a portable condenser microphone in each cab compartment for use by the engineer. In addition to the basic audio applications, a recording video system shall be included to achieve the requirements of SEPTA’s present Video Surveillance System (VSS) as presented below.

13.1.1 Controls

The cab or radio shall be equipped with a condenser microphone and the Engineer shall also be able to use an external lapel microphone that will cut-out the condenser microphone when inserted into the microphone jack. A push-to-talk button shall be located at a convenient location.

13.2 TWO WAY RADIO.

The Contractor shall provide a Ritron RCCR-151 “Clean Cab Radio” in each cab with one antenna for each cab. The Contractor shall install the radio and wire, cabling and power in each cab engineer’s console. The location, wire, cabling, and power arrangement shall be approved by SEPTA. The radio shall be capable of operating throughout the low voltage range for the locomotive as 74 volts DC, nominal.

It is intended that the integrated radio transceiver be flush mounted on the cab console panel, using a slide-out mounting. Sufficient cable slack shall be provided for ease of servicing or replacement. The radio transmit control shall be by means of a dedicated pushbutton located in a location to be approved by the Engineer, arranged for ease of use. All other control over the radio transceiver shall be performed by use of the radio faceplate controls and indicators. If possible, the radio faceplate transmit pushbutton should also be kept functional, for redundant hand operation.

The radio case and the antenna shall be securely grounded to the carbody to ensure an excellent standing wave ratio.

13.2.1 VHF ANTENNA

The antenna connected to the locomotive voice radio shall be a Sinclair Excaliber ST221 or SEPTA-approved equivalent and shall be installed on a flat mounting plate on the centerline of the roof over each cab compartment. All mounting and conduit holes shall be fully watertight. Removal and installation of the antenna shall be possible from the roof of the locomotive without requiring access to the underside of the roof.
13.3 CONDUCTOR SIGNAL

The cab will be equipped with a conductor signal buzzer (communication trainline #22 74VDC). This buzzer shall alert the engineer to request to communicate and/or to proceed. The buzzer shall be of an electronic type.

13.4 MU TRAINLINE

The locomotive shall be capable of operation in push-pull and multiple unit service with any SEPTA or standard AAR trainline equipped locomotive. During this type of operation, the MU controls and communications shall be interfaced using the existing 27-pin jumper arrangement trainline protocol.

13.5 ONBOARD VIDEO SURVEILLANCE SYSTEM (VSS)

13.5.1 General

The locomotive shall incorporate a Locomotive Digital Video Recording System (LDVR) to meet the requirements of the SEPTA Video Surveillance System (VSS). The video data acquisition system shall monitor and record data acquired from multiple on-board camera sources that shall be arranged to maximize the coverage of the activities associated to the locomotive and its operations.

The on-board camera system shall have day and night capabilities and provide high quality color video necessary to monitor the movements of all operational activities, both within the cab and forward facing installations.

The integration of the system circuitry and equipment shall be fully represented in the locomotive’s reference schematics, manuals and training.

13.5.1.1 Video Recording System

The VSS equipment shall consist of an Interloix Mobileview PENTA 16 Channel recording system with 2 TB of storage, and include recording capabilities for a minimum of two audio channels.

The system in operation shall provide adjustable frame rates necessary to avoid latency and/or frame loss that would cause discontinuity of motion and loss of apparent causal circumstance. SEPTA currently requires ten (10) frames per second.

All acquired data shall be written, stored and encrypted. All data shall reside on the rail vehicle, on a Hard Disk Drive (HDD) device that is designed and applied for the purpose of mobile data acquisition and storage.

Data acquired in this mode shall be high quality to allow monitoring personnel to view data that equals the quality of data written on the Vehicle HDD device. Authorized SEPTA personnel shall have the ability to access all data online and download all data to wayside PC based systems without loss of storage and quality of data stored on the Vehicle HDD system.
The SEPTA local server system(s) shall facilitate data movement to other specified locations and user groups through wayside access points.

The Contractor shall provide a feature that allows the user to select a time frame to obtain captured time stamped video to be transferred to wayside access points located at Wayne, Overbrook, Frazer, Powelton, and Roberts. Date and time for the recorder shall be obtained from the locomotive’s systems clock.

The system shall be configured to record data from all cameras as long as a cab is active in the consist, and for 90 minutes after the cab makeup trainline is deactivated. The system must power down properly in the event of an abrupt power loss. The system shall feature a safe shutdown mode to ensure all data is saved to the recording device properly.

The Contractor shall provide Wi-Fi and WiMAX units and antennas to support GPS, Wi-Fi and WiMax on separate cables, equipment and arrangement to be approved by SEPTA. Two microphones capable of interfacing with the audio recording capabilities of the VSS shall be provided, mounted in a location to be approved by the Engineer.

13.5.1.2 Video Cameras

A minimum of 12 video cameras shall be used to meet the VSS requirements for the locomotive in the following locations and camera quantities:

- One forward facing camera shall be installed at each cab, totally two forward facing cameras per locomotive. The location of each camera must allow the camera’s field of view to be within a clean, viewable area of the windshield (within the path of the wipers). The cameras shall be hooded to reduce glare.

- One camera shall be trained on the engineer’s operating position in each cab, totaling 2 per locomotive.

- A camera shall be located on the exterior of the locomotive next to each door and trained to show the cab steps of the rear cab and consist of the train. Rearward views from both the left and right side cameras shall also be displayed upon the console in each cab. There will be 2 cameras at each end thus making the total camera quantity 4 cameras for this application.

- Each pantograph shall be monitored by dedicated roof mounted camera installed in a location to fully show the pantographs operation during use. With two pantographs, a total of two cameras per locomotive shall be needed for this application.

- One machinery room walkway camera shall be installed just forward of the cab door in the machinery room at each end of the car. A total of two cameras shall be needed for this application.

Installation and location of all cameras are subject to SEPTA approval.
13.5.1.3 Recording Equipment Installation

The audio/video recording system components (except the cameras) shall be installed in a secure keyed locker.

The audio/video cable connecting the camera to the recording system shall be routed in a dedicated conduit. A separate sealable 74 VDC circuit breaker shall be provided in the circuit breaker panel for the recording system.

13.5.1.4 Wireless download

Wireless download shall be at 802.16 WiMax protocols. The transmission distance shall be a minimum of 1500 feet, to be compatible with SEPTA’s existing WiMax infrastructure.

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14 LOCOMOTIVE MONITORING, DIAGNOSTIC SYSTEMS AND TEST EQUIPMENT

14.1 GENERAL DESCRIPTION

The Locomotive Data Management System (LDMS) referenced is hereby designated the locomotive health monitoring and analysis system which is a wireless health onboard monitoring and analysis software. The system shall download onboard system faults and transmit via wireless to a server for further analysis with SEPTA’s existing wifi infrastructure in Suburban Station and SEPTA’s five shop and yard locations. Along with health monitoring, this onboard system shall also have GPS functionality which will be viewed through the same server.

Shop-located test equipment, enabling SEPTA to qualify locomotive replaceable components, shall be provided. Test and alignment equipment and "Special Tools" for mechanical equipment shall also be provided.

SEPTA requires a highly reliable data acquisition, recording and transmission system that shall combine the functions of most or all of the locomotive’s auxiliary electronics equipment. The system shall combine in one equipment rack such functions as memory, fault information transmission, data communications and operational on-board reporting.

Additionally, the Contractor shall provide fault diagnostics with health data storage and strategic maintenance predictive capabilities for module or component replacement or end-of-life cycle predictions. The system shall provide wireless downloading of locomotive fault data in real time and shall be expandable to include the entire train. The system shall transmit and receive all messages for customer services and transportation operating requirements. A train network, to be approved by the engineer, shall provide a non-proprietary, open interface, allowing bi-directional operational on-board reporting, fault information transmission, and data communications with the entire consist. The network provided shall enable the communication between multiple locomotives, as well as provide capabilities for communication between locomotive and future fleets, including single-level and multi-level passenger coaches. The system shall be extendible to allow operations, diagnostics, and fault information screens to be defined at a later date by SEPTA for full integration of subsequent fleets.

The system shall have the equipment, software and data buss network capacity for future growth and system upgrading.

The diagnostic equipment shall be modular, using solid state technology. Modules shall be housed in a single location in a crash-resistant electronics cubicle, sealed against dirt and contamination encountered in normal railroad operations.
14.2 LOCOMOTIVE MONITOR REPORTING

The locomotive monitor shall provide the means to report on the condition of the locomotive equipment using a wifi system. This system shall be GPS equipped. It shall provide an isolated USB or an Ethernet connection for real-time access to diagnostic and status information. The communication protocol shall not be password protected or encrypted and allow access to all data remotely through the referenced wireless communication equipment. An interface control document shall be provided detailing the messaging protocol to request the required data. Access to the real-time data shall not impede the normal operation of the locomotive.

14.2.1 Health Reporting

Each subsystem controller in the locomotive shall have self-diagnosing capability as specified in Section 2.4. The locomotive monitor shall provide the function to collect operating status and fault conditions from each controller and distribute the data for display to the appropriate location. The locomotive monitor shall have the capability to prioritize the data and provide instructions to the train crew. The on-board displays shall be located as specified in Section 5.3. The type and hierarchy of data to be displayed at each location shall be established and approved by SEPTA during design review.

14.2.2 Maintenance Reporting

Each subsystem microprocessor controller in the train or locomotive, as part of its self diagnostic capability, shall develop and maintain data pertinent to forecasting the time of its components’ reaching end-of-life or out-of-tolerance conditions by the analysis software. The diagnostics used by the controllers shall include parameter measurement and cycle counts during operation.

The monitor shall periodically poll the subsystem controllers to amass this data into a Train Maintenance Requirements report. The frequency of this report shall be established during design review. The Train Maintenance Requirements report shall be downloaded, via wireless communications (see Section 14.2.7), to a wayside maintenance facility as requested. The monitor shall be capable of storing a minimum of 3000 events with a date and time code for each event. The capability shall be provided to reproduce a copy of the report at the LDMS workstation.

14.2.3 Extraordinary Data Reporting

Extraordinary data are the detailed time-history records, centered on a specific fault, stored in the RAM of an individual system controller. This data may be requested while the train continues operation or by a technician in a service area or on board the train. The monitor system shall be capable of receiving these requests via wireless Interface from the LDMS workstation.

14.2.4 Automatic Monitoring

The design features contained herein shall be addressed in the overall automatic monitoring and control of the LDMS:
1. Bearing Overheat
   Activation of a bearing overheat alert shall be dealt with in the same manner as fire detection and in a manner dictated by the operating rules.

2. Head End Power Status
   Failure of a HEP unit shall be indicated to the Engineer with a recommendation for the appropriate action.

3. Horn and Bell
   Operation of the horn and bell shall be audibly monitored by the Engineer, no automatic locomotive response required.

4. Dynamic Brake
   A dynamic brake or line receptivity failure shall be annunciated to the Engineer with a recommendation for the appropriate action.

5. Friction Brake
   If a problem arises resulting in less than the designed braking capacity being available, the Engineer shall be informed so that operating restrictions can be imposed.

Whenever a monitored parameter exceeds its predetermined limit, the event shall be logged in the LDMS and the operating Engineer shall be provided a notice of the event. As defined in Section 14.2.1.1, the Locomotive monitor shall provide instructions to assist the crew in handling routine operations and operational fault conditions.

The Safety Program, Section 2.5 shall be used to identify the various levels of risks and hazards. Items identified as safety critical shall be implemented in a fail-safe manner and shall include a vital means to monitor and control system failures. The Locomotive monitor shall be used to provide this monitoring and control function.

### 14.2.5 Basic Data Access and Capability

Data related to out-of-limit performance events that occur during locomotive operation shall be monitored in the LDMS for storage and transmission by wireless download. The recorded data shall also be directly downloaded on demand to a computer with the latest version of Microsoft Windows at NTP and USB memory device. The primary on-board downloading system shall be the USB memory device.

The LDMS shall continuously monitor locomotive health with information on overhaul periods, component change-outs, fault diagnostic routines, and locomotive performance parameter limits. Critical devices and systems shall be identified as part of the fault diagnostic information to be scrutinized by the LDMS analysis software.

All major equipment shall be monitored, including basic operation such as input and output currents, operating temperature, or any method that shall assist in determining the health or status of the equipment.
Sufficient memory shall be provided to store and record at least 500 out-of-limit events, with a capacity of 750 to 1000 events in the compressed mode. Newest data shall replace oldest data in this memory. An event message shall occur for fault transmission of out-of-limit events.

The system shall identify items causing problems or faults, and shall record information to help establish the effect or failure problem. It shall identify the cause and suggest recommended action (e.g., Effect: “Intermittent Speed Sensor”. Action: “May continue to operate but need to replace the sensor on #4 traction motor.”)

14.2.6 Data Download

General recorded data shall be compatible with retrieving information in Microsoft Excel format onto the display screens located in the cabs or by the use of a portable computer. There shall also be an automatic download capability to a standard USB memory device from the cab screen. The download capability in each cab shall allow downloading at any time, even during operation, using the following methods:

- A standard USB memory device shall be used as plug and play which shall initiate automatic download upon plug in. Data shall auto download in Excel supported format onto the standard USB memory device.

- Direct downloading using a USB cable onto a portable PC. Each connector shall be a standard USB A to A cable.

- The software package shall incorporate both methods to download data and shall be compatible with latest series microprocessors and the latest version of Windows software.

- With the proper electronic key authority to access the system, maintenance personnel shall be able to retrieve information on selected cab screens in the locomotive even when the locomotive is in service.

- Five cables shall be provided prior to delivery of the first locomotive, together with five latest series color Windows based portable maintenance computers.

- To facilitate data download, the Contractor shall provide one 120VAC duplex power outlet and one 74 VDC single power outlet in each cab. A second 120 VAC duplex power outlet shall be placed in the machine room near the control systems to be used during testing, servicing or troubleshooting the locomotive. The outlets shall be permanently and clearly labeled and protected by circuit breakers. The outlets shall have an uninterrupted power supply receiving their power via an inverter from the main locomotive battery to allow power to be available even when the locomotive is shut down. Inverter rating shall be a minimum of 1KVA.

14.2.7 Wireless Data Links

A multiplexed data buss link shall be provided between locomotives and a Conductors terminal in a data link-equipped locomotive. Requests for assistance messages shall be sent to the locomotive for temporary storage while awaiting transmission to the WI-Tronix system.
14.2.8 Display Panels and Screens

Two solid state flat display monitor panels shall be mounted on the operator’s console in direct frontal view just below the line of vision of the operator. CRT displays shall not be permitted.

Warming devices, to maintain display operating environment, shall be permitted for low temperature operation below -22 °C and cooling shall be provided to ensure proper operation in the high cab temperatures. Note that HVAC is not to be used for cooling and heating of the display screens or electronics.

Information concerning locomotive operating data shall be presented for ease of visual recognition in compliance with AAR recommendations.

Alternate proposals for displays shall be considered during design reviews to take advantage of improved technology. Enhancements to include color graphics, variable intensity and contrast controls, increased temperature range, and display clarity are critical features for review. AAR specifications shall be incorporated where appropriate.

The displays and screens noted in this Specification are for use as a guide for proposals and system development. Text must be written in plain, simple English for non-technical personnel.

For purposes of this Section, “displays” shall be considered the hardware on which the informational screens appear. The term “screens” is used to refer to the individual blocks of information which appear on the displays.

Each display panel shall be touch screen or have an adjacent user obvious touch pad to access alternate screen options available to the viewer. Information shall be available in different levels of security:

- Information that shall be displayed continuously to the viewer. This information type contains “VITAL” information. It shall have screen priority.

- Information that shall be displayed as requested by the viewer. This information shall have lowest screen priority.

- Information that shall be displayed by exception or by occurrence of an event. When the exception or event occurs, the information shall be displayed continuously until an acknowledgment action is taken. This information type shall have screen priority over requested information.

- Secure Information that shall be displayed on demand to authorized personnel only. An access code shall be required.

- Optional information that may be available to the viewer at SEPTA’s discretion. The format, type of available information, and the security methods involved shall be subject to design review.
The primary display panels in the operator’s console shall contain information essential to the operation of the locomotive. Two display panels shall be provided. Panel One shall contain essential locomotive operational information that appears continuously.

### 14.2.9 Strategic Maintenance

The locomotive shall incorporate strategic maintenance concepts that shall:

- Minimize train delays caused by locomotive failures.
- Maximize cost effectiveness of locomotive maintenance by introduction of just-in-time component change-out.
- Predict wear out.
- Reduce troubleshooting time.
- Minimize required fleet size by improved equipment utilization.

This approach shall be based on microprocessor-based equipment to measure and log real-time performance and faults. Health monitoring shall be used to direct maintenance personnel to:

- Service equipment close to the end of its useful life, but before failure (e.g., air filters).
- Service equipment operating beyond presently accepted values, but not yet failed (e.g., air conditioning unit operating, but at limited capacity because it is low on refrigerant).
- Repair defective equipment by directly identifying the failed component.
- Repair defective equipment that has not been reported.
- Ensure that before equipment is dispatched, all systems are working properly.
- Statistically analyze trends so that corrective action can be taken (e.g., electronic equipment running hot, repeat failures of the wheelslip speed sensors on a vehicle, etc.).

### 14.2.10 Health Monitoring System

The health monitoring system shall continuously monitor locomotive health by using fault diagnostic routines and checking performance parameter limits which can be used by maintenance personnel and crew to establish the operational status of the locomotive.

Flow rates, temperatures and pressures shall be measured and compared with known out-of-limit settings for liquids, air, oil, freon, etc. Cyclic operating devices such as contactors, valves, limit switches, etc., shall have their operations counted and compared with established reliability statistics. Electrical loads, pressures, temperatures, etc., shall be monitored to establish any developing trends towards out-
of-limit conditions or that are abnormal to the particular circumstances existing. Fault messages may use a code number, but the message displayed on the screen must include an easily understood basic English text.

Out-of-normal-range and fault data shall be collected from all major locomotive systems and made available as follows:

- To the Operator, when conditions occur that require action within the next 5 minutes. This information shall be displayed on the screen and an audible alarm sounded.
- To maintenance facilities via wireless data transfer.
- To maintenance staff via USB memory device.
- To maintenance staff via USB or Ethernet port.
- To maintenance staff via screen in response to prompts.

When a fault occurs which threatens train safety, performance or passenger comfort, the fault message shall be transmitted immediately and continue repeating until a successful transmission occurs. Periodically, recent fault data shall be downloaded to the maintenance facility as the train nears the terminal to allow supervision to plan locomotive material and staff requirements and to minimize turnaround times.

To the maximum extent possible, the health monitoring system shall use only existing sensors, transducers, switches, etc., already present in the equipment being monitored and shall be an integral part of the existing microprocessor controls.

System reaction time is important and data shall be displayed in real time with changes in status displayed immediately in less than 1 second increments. Parameters which change slowly, such as coolant temperature, or those not directly involved with operating the train, may incur a time delay not to exceed two seconds.

The health monitoring system shall automatically perform a self-test when the locomotive is activated, and shall initiate a complete or partial locomotive self-test upon demand. A terminal brake test, including monitoring for car brake applied and release trainline response, shall also be part of the test sequences.

It shall be possible to ascertain the current software version of all systems utilizing a microprocessor via system displays and data downloads. Initiation of sub-system self-test by maintenance staff, as a diagnostic and troubleshooting tool, shall be possible using on-screen prompts. To the maximum extent possible, the on-board self-test, self-diagnostic, and annunciation functions shall provide indication to maintenance staff the capability of isolating defects to the lowest replaceable units.

The entire health monitoring system shall be subject to a design review to ensure that the basic concepts are compatible with SEPTA’s requirements.
14.3 TEST EQUIPMENT

14.3.1 Bench Test Equipment

To allow the proper testing, troubleshooting and calibration of locomotive components on a test bench in a specialized workshop environment, the Contractor shall supply two complete sets of each type of bench type shop test equipment. Each tester shall be delivered as a completely wired and assembled unit, and use shop electrical power and/or compressed air. Each tester shall have a receptacle for connecting to the device under test. Ease of operation to provide various inputs and for measurements of all signals shall be provided. The connections to the device under test, if not contained in the receptacle, shall be from the front of the tester and shall have provisions to neatly store out of the way when not needed. Extensive rear-mounted connectors shall be provided to allow interconnections with supplied generic test equipment, without a mass of jumper wires being necessary. The test units shall be for use in several SEPTA shop facilities. The Contractor shall coordinate with SEPTA to ensure compatibility with SEPTA’s maintenance facilities.

Testers shall be used for the purposes of testing, troubleshooting, and calibrating electric, electronic, mechanical, pneumatic and electro-mechanical components of each locomotive subsystem. They shall contain provisions for the rapid testing, troubleshooting and calibration of each and every type of electronic circuit board including motherboards and backplane wiring, plug-in relay, current sensor, speed sensor, transducer, friction brake element, module, pressure switch, etc., used in any car system. Design of the testers shall be such that all inputs can be varied over the full working range of the device.

The bench test equipment shall be designed to enable a technician to perform rapid testing, troubleshooting to the discrete component level, repair and calibration of all equipment. The bench test equipment shall be automated to the extent possible so that a technician need only plug in or hook up a component for testing, identify the board or component, and the automatic test shall begin. This automatic test shall indicate the health of the unit under test and if the unit is acceptable for service or not, this shall include an evaluation of the unit’s calibration status. If the unit under test is declared defective or out of calibration, the bench test unit shall allow the technician to troubleshoot the defective unit to determine which component is defective. For example, if a printed circuit board is under test and it is identified as being defective, the bench test unit shall allow the technician to single step through the automatic test to maintain the required inputs to the board for troubleshooting by the technician, which may include probing the circuit board to make various measurements, to determine which component, such as a resistor, capacitor, transistor or IC chip, is defective. It shall also include a manual mode to allow application of inputs to the unit under test as selected by the technician for troubleshooting. The Contractor shall supply all hardware and software required for perform these functions, for approval by the Engineer.

Each supplier of circuit boards under this contract shall supply SEPTA all necessary electrical and physical information needed for fault finding and repair testing of these boards on this shop equipment. The shop testers shall be preprogrammed by the Contractor with algorithms needed to test and diagnose all of the car’s circuit boards, as determined by the Engineer. Suppliers of circuit boards shall provide the information require to program the shop testers in a format designed for ease of entry and implementation by the Contractor.
For each item of shop bench test equipment, one set of all peripheral test equipment required to make the necessary tests and adjustments, such as frequency generators, digital voltmeters, oscilloscopes, etc., shall also be provided. They shall be rack mounted adjacent to and rear connected to the specialized equipment such that the end result is neat and tidy. These items shall be premium quality heavy duty devices supplied by Hewlett-Packard, Tektronix, Fluke or other similar-quality approved supplier. The bench test equipment shall include all support devices required to enable testing of the line replaceable unit without the need to remove additional equipment from the car to support use of the bench test equipment.

Shop test equipment shall be provided for, but not limited to, the following:

a) Propulsion control and power units  
b) Dynamic brake control and power units  
c) Wheel spin/slide control unit  
d) HEP units  
e) Low voltage power supplies  
f) Friction brake elements  
g) All printed circuit boards  
h) Plug-in relays  
i) Automatic train control/positive train control/event recorder  
j) Communications system, including radio and communications control units  
k) Heating and air conditioning control  
l) Vehicle Location System/GPS control units  
m) Microprocessor, EPROM, EEPROMs and other electronic device reprogramming for all car systems, except as approved by the Engineer  
n) All electronics units not identified above

Test instruction manuals which comply with the requirements given in Section 17 and schematics which comply with the requirements of Section 1.17 shall be provided. The test manuals shall include operation of the tester, repair of the tester, and specific test instructions for each unit of electronic apparatus.

Test and alignment equipment shall also be provided for all mechanical components requiring fixtures, alignments, testing or special handling. Two complete sets of test and alignment equipment are required.

14.3.2 Special Tools

Any "Special Tools" (fixtures, adapters, etc.) shall be supplied by the Contractor. "Special Tools" are any tools not ordinarily commercially available and are made for a specific purpose. Drawings of these tools shall be provided. The quantity of special tools provided shall be consistent with the needs to meet the maintainability requirements of Section 2.8.
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15 MATERIALS AND WORKMANSHIP

15.1 GENERAL

Materials and workmanship shall be in accordance with the requirements of the Specification unless otherwise approved by SEPTA.

Inclusion of a material or method in this Section shall not necessarily indicate approval for application or use in a specific situation. Specific requirements detailed in other sections of this Specification shall take precedence over materials or methods specified in this section.

Material Safety Data Sheets (MSDS) shall be submitted for all materials, used in the fabrication of the locomotives. This requirement shall include lubricants but excludes non-hazardous metallic materials. Information shall be in a form compliant with ANSI Z400.1-1993

15.1.1 Cleaning Agents

A list of recommended cleaning agents shall be provided to SEPTA for all materials exposed to normal cleaning operations. This information shall also be included in the maintenance documentation for the vehicle.

15.1.2 Prohibited Materials

The following materials are prohibited from use on the locomotives:

- PVC
- Asbestos
- Cadmium (except for battery)
- Lead (except for battery)
- PCBs
- Carcinogenic materials
- Lumber
- Materials listed in 29 CFR Sec. 1910.19

Recyclable Materials
Expendable plastic items that are recyclable shall be identified with the appropriate symbols, as defined by the Society of the Plastics Industry, permanently imbedded in the material.

15.1.3 Marking

All materials intended for use on these vehicles shall be marked or stored so as to be readily identifiable and shall be adequately protected during handling and storage. Rejected material shall be clearly marked and stored in an area specifically designated for that purpose.

15.1.4 Material Handling

The Car builder shall exercise care in the handling of all material used in construction. Examples of mishandling material include but are not limited to the following:

- Exposure to corrosives or other elements that may deteriorate the subject material
- Inappropriate storage (stacking beyond packaged limits, careless placement of material)
- Dragging materials across rough surfaces that may cause damage (e.g. dragging cables)
- Stretching materials during handling
- Exposure of certain materials to excessive UV light
- Products past their expiration date shall be destroyed

SEPTA reserves the right to direct the Contractor to change material handling methods if it is deemed necessary.

15.2 STANDARDS

15.2.1 General

This Section contains a partial listing of both government and industrial standard which generally apply to this Contract. All standards shall be current versions as of Notice To Proceed unless otherwise indicated. These standards shall, as a minimum, apply whether referenced or omitted in the text of any of the preceding Sections of the Specification, drawings, or other documents. When other standards are identified within this Specification, the most rigid requirements shall apply.

Where other or foreign standards are proposed by the Contractor, the Contractor shall submit documentation for SEPTA review and approval demonstrating the proposed standards are the equivalent of the specified standards and specifications. Proposed substitute specifications shall be submitted in both English and the language of the country of origin. The Contractor shall be responsible for assuring accuracy that the English translation is correct. The approval of the alternate standard by
SEPTA does not in any way relieve the Contractor of responsibility for the proper function, the adequacy of the design, or Specification compliance.

15.2.2 Government Standards

The following government regulations and documents shall be part of this Specification:

- Federal Railroad Administration (FRA) Department of Transportation (DOT)
- FRA/DOT Code of Federal Regulations, Title 49, Transportation, Section II, Parts 200-299.
- FRA/DOT publication, Safety Appliances and Power Brakes.
- Occupational Safety and Health Administration (OSHA)
- Department of Labor publication, General Industry Guide for Applying Safety and Health Standards.
- U.S. Department of Health, Education and Welfare U.S. Public Health Services (USPHS)
- Publication, Food Service Sanitation Manual
- U.S. Department of Agriculture (USDA)
- Forest Products Laboratory Report No. 1837
- Federal Specifications
- Primers for Metals other than Stainless Steel, TT-P-664
- Aluminum Paint, TT-P-38D
- Military Specifications
- Plymetal Panels, MIL-P-8053
- Protective Finishes, MIL-HDBK-132
- Finish Paint, MIL-E-15090, Class 2
15.2.3 General Industry Standards

The following documents form a part of this specification. Unless otherwise indicated, the issue in effect on the date of Notice to Proceed shall apply.

- **Association of American Railroads (AAR)**
  - All materials, parts, and workmanship shall, as a minimum, conform to AAR requirements and the applicable sections of AAR manuals, standards, and recommended practices as follows:
    - Castings, AAR Specification M-201, Grade B
    - Air Brake Piping, AAR Specification 2518

- **Aluminum Company of America (ALCOA)**

- **Aluminum Association**
  - Aluminum materials shall conform to the following publications:
    - Aluminum Standards and Data
    - Specifications for Aluminum Bridge Type Structures
    - Engineering Data for Aluminum Structures

- **American National Standards Institute (ANSI)**
  - All fasteners, splines, keysets, chains, gears, bearings, pipe fittings, pipe threads, and miscellaneous parts and equipment shall have form, fit, and function in accordance with ANSI standards and specification:
    - Screws, Bolts and Nuts, ANSI-B18

- **American Society for Testing Materials (ASTM)**
  - All materials and testing of materials shall be certified by tests, type tests, and/or certifications to meet the requirements of the applicable ASTM Standards and Tests, latest edition, as follows:
    - Stainless Steel, ASTM A666
    - High Strength Low Alloy Structural Steel, ASTM A 572, A 588, A 606, A 715, A 710
- Aluminum Alloy Castings, ASTM Specs. B 26, B 85, B 108
- Accelerated Aging-Rubber Products ASTM D 573

- American Society of Mechanical Engineers (ASME)
The following procedures of the ASME shall be adhered to, to the extent specified herein:
  - Welding and Brazing Procedures and Performance Qualification code.
  - Boiler and Pressure Vessel code.

- American Welding Society (AWS)
  Practices, methods, processes, and recommendations of the AWS shall apply to the extent specified herein, and specifically:

- National Fire Protection Association (NFPA)
  Wiring shall be in accordance with NFPA methods and materials to the extent specified herein, and specifically: NFPA Publication No. 70 (NEC).

### 15.3 JOINING AND FASTENING

#### 15.3.1 Joining

**15.3.1.1 General**

Certain combinations of materials require particular care in joining to avoid the possibility of corrosion. The contractor shall design the vehicles to minimize the number of such combinations, and to minimize the accumulation of water, cleaning chemicals, and chemicals present in the environment, at or near combination joints. Isolating and moisture-proofing materials, appropriate to the materials being joined, shall be used at all times where these combinations exist. The contractor shall provide a detailed plan for installation of dissimilar materials in accordance with these sections and applicable industry practice. This plan shall be submitted for approval by SEPTA prior to beginning of assembly of the first vehicle.

**15.3.1.2 Joint Fitting**

Joints shall be properly fitted, whether exposed or concealed. When not otherwise specified in Contractor drawings or specifications, gaps between joints shall be held to a dimension not greater than 10 percent of the thinner material being joined, or 0.002 inch, whichever is greater. Gaps shall be uniform in width across 100 percent of the surface. The edges of panels shall have a smooth, finished appearance.
Where excessive gaps (greater than those permitted by approved drawings or standards) are found to exist at the faying surfaces of structural bolted or riveted connections, metal shims of the same material as that of the deficient part may be used, but only with the written permission of SEPTA. Shims, if used, shall be permanently fastened to one of the base parts being joined. The use of epoxy or other plastic filler at such locations is expressly prohibited.

15.3.1.2.1 Metal-to-Metal Connections

Where metals contact each other, the contact surfaces shall be free of dirt, grease, rust, and scale. Unless specified otherwise, the contact surfaces shall be coated with a metal based primer which conforms to Society for Protective Coatings, Specification SSPC-Paint 25. Metal primer may be omitted for austenitic stainless steel to austenitic stainless steel joints.

15.3.1.2.2 Wood-to-Wood Connections

Where wood and wood are placed together, both abutting surfaces shall be coated with aluminum paint conforming to Federal Specification TT-P-38.

15.3.2 Fasteners

15.3.2.1 General

The Contractor and suppliers are responsible for selecting fastener types, sizes, styles, lengths, materials, grades, and finishes that shall meet the requirements of this Specification. The Contractor shall minimize the number of different sizes and styles of fasteners used. Throughout the locomotive the use of inch standard fasteners is preferred. However, ISO Metric fasteners may be used in conformance with Section 15.3.2.2.

All fasteners used on this vehicle can be classified under one of four categories: critical; general purpose; decorative; or electrical and electronic. The criteria for classification are expressed below. All fasteners must meet the general requirements for design and material in addition to any requirements contained in the section specific to the particular category. No underfloor equipment weighing over 50 pounds shall be supported solely by fasteners.

Critical fasteners include, but are not limited to, all fasteners applied to locomotive structure, trucks, bolsters, truck-mounted brake equipment, couplers, and power collection devices. Additionally, any fastener is considered critical if failures cannot be tolerated, that is, if even a single fastener fails there is a possibility of brake failure, derailment, or accident. In the event of a dispute, SEPTA shall be the final arbitrator on which fasteners are classified as critical.

Fasteners used to attach interior lining or trim and exposed to personnel view are specified under Decorative Fasteners.

Fasteners used to secure wire terminations to an electrical or electronic device are considered Electrical and Electronic, and are specified in elsewhere in this section.
Fasteners not falling into one of the other three categories are classified as General Purpose.

15.3.2.2 Threaded Fastener Standards

15.3.2.2.1 Inch-Standard Fasteners

All inch-standard threaded fasteners shall conform to ASME B1.1 Standard, Unified Inch Screw Threads, (UN and UNR Thread Form) or Industrial Fasteners Institute “Inch Fastener Standards”.

15.3.2.2.2 Metric Fasteners

Upon approval, specific Line Replacement Units (LRUs) that are provided by a supplier or sub-supplier to the Contractor may be supplied with metric fasteners to ANSI B1.13M (ISO-metric) Standards. In these cases, all internal fasteners and threaded components of the approved unit shall have ISO-metric threads. Internal to components there shall be no mixing of metric and inch threaded fasteners. External mounting fasteners and threaded connecting components shall have ISO-inch threads to ASME B1.1 Standards. Each unit, component, or group containing ISO-metric threads shall be indelibly identified, in an approved manner and in a conspicuous approved location, to signify that the unit contains metric threaded fasteners. All repair and maintenance manuals shall be conspicuously marked on each page where metric threaded fasteners were used within the unit. Replacement, repair, or maintenance parts supplied under this Specification shall contain all necessary replacement fasteners of the correct size and grade.

Metric fasteners shall be marked as required in “Metric Fastener Standards”, Industrial Fasteners Institute, latest edition.

15.3.2.3 General Requirements

1. Fastener Materials and Coatings

When making connections to heat producing apparatus, thermal expansion of the components shall be taken into consideration for selection of fastener materials. If the joined components are high expansion alloys such as copper or austenitic stainless steel, austenitic stainless steel fasteners shall be used. If the joined components are low expansion materials such as carbon steel or ferritic stainless steel, zinc plated carbon steel fasteners of minimum Grade 5 shall be used.

All carbon, alloy, and martensitic stainless steel fasteners shall be plated with zinc, unless specifically waived by SEPTA. Cadmium plated fasteners are not permitted. Grade 8 or metric grade 10.9, or stronger, fasteners shall not be plated if the OEM finish is other than plating. The zinc plating shall conform to ASTM B633 SC2 Type II, SC3 Type II, or SC4 Type II, or ASTM B695, Class 8, Type II.

Alternate fastener coatings are permissible if qualified by testing per ASTM B117 with no red rust or visible corrosion products after 96 hours of exposure. The Contractor shall submit
qualification results for each process used at each subcontractor applying the proposed coating.

In order to use an alternate coating, the vendor shall submit 1) coating manufacturer’s product data including required thickness, 2) ASTM B117 test results from an accredited third party laboratory, 3) documentation of torque/tension characteristics, and 4) a statement from the coating manufacturer regarding the propensity for the coating process to cause hydrogen embrittlement of the fastener during coating. Regardless of the coating’s propensity for hydrogen embrittlement, each lot of high strength fasteners, including OEM plated zinc or yellow bolts (Grade 5 or Metric Grade 8.8 or higher) shall be tested for hydrogen embrittlement in accordance with Section 15.3.2.3. Each lot of lower strength fasteners shall be tested for hydrogen embrittlement if the coating has the possibility of causing hydrogen embrittlement.

If the proposed coating results in a change in the K-value for the plated fastener to outside the range of 0.13-0.15, as defined by Industrial Fasteners Institute Standard IFI-543, the vendor shall use the alternate coating on all fasteners within the particular LRU. The LRU shall contain an indelible label identifying the coating type used within the LRU and the required torque values for each size fastener used therein. Fasteners internal to a subcomponent within an LRU may use the standard coating system if they are not subject to removal during Owner’s maintenance activities.

2. Requirements for Nuts

   Unless otherwise required by a specific application, all nuts shall be regular height, nylon insert, self-locking stop nuts (ESNA or approved equal), conforming to Military Standard MS-21044 and Military Specification MIL-N-25027. Where nylon-insert self-locking stop nuts cannot be used, self-locking bolts and screws conforming to MIL-DTL-18240 Type L may be used. Nylon insert lock nuts, bolts, or screws shall not be used near heat sources that shall exceed the manufacturer’s recommended operating temperature or 200°F, whichever is lower.

   All-metal prevailing-torque type locknuts shall only be used where there is insufficient clearance to install ESNA type locknuts, or where the locknut is exposed to temperatures above 200°F.

   Clip nuts shall not be used.

   All carbon, alloy, and martensitic stainless steel nuts shall be plated with zinc, unless specifically waived by SEPTA. Grade 8, or metric grade 10.9, or stronger, nuts shall not be plated if the OEM finish is other than plating. The zinc plating shall conform to ASTM B633, SC2 Type II, SC3 Type II, or SC4 Type II, or ASTM B695, Class 8, Type II.

   Alternate coatings may be applied to nuts per the requirements of Section 18.3.2.3.1 and 18.3.2.3.3

3. Washers and Retention Devices

   Washers, of a grade and strength compatible with the fastener, shall be used under the heads of all bolts and under all nuts. Washers shall conform to ANSI B18.22.1 or ANSI
B18.22M, latest revision, as is appropriate for the application. Where high strength fasteners are applied, washers shall be hardened and comply with IFI Fastener Standards.

Lock washers shall not be used for fatigue applications where the fastener must be torqued and marked per Section 18.3.2.3. The use of lock washers is discouraged throughout the vehicle and all systems. Other types of washers, including Belleville washers, may be used for special applications with SEPTA’s approval. Lock washers, when applied, shall conform to IFI Fastener Standards.

4. Joint Design

All screws or bolts used to secure access panels to the interior, undercar, or roof equipment shall be made captive to the panel in which they are used. All fasteners used to secure access covers, doors, or panels to equipment boxes or interior panels shall be made captive to the panel in which they are used. Where access for service is expected more often than every five (5) years, access panels shall be equipped with quarter-turn fasteners. Quarter-turn fasteners shall have a minimum shank diameter of 0.25 inch, be of adequate strength, and as manufactured by Southco, or approved equal.

Unless otherwise approved by SEPTA, threaded fasteners shall not be threaded directly into non-metallic materials. Metal thread inserts shall be used when a threaded fastener is secured to a non-metallic material.

When bolts are used to secure apparatus where the bolt head is not accessible, a reusable mechanical locking device shall be used to prevent the bolt head from turning when the nut is being turned.

At least 1-½ screw threads shall be visible beyond all nuts. When used without elastic stop nuts, bolts shall not project more than 1-½ threads plus 0.25 inch for bolts 0.25 inch diameter or less and shall not project more than 8 threads for larger diameter bolts, unless otherwise approved. With elastic stop nuts, bolt threads shall not project more than 0.25 inch, regardless of bolt size.

Undercar equipment shall not be supported by bolts in tension. On a case by case basis, where redundancies exist, SEPTA will consider this mounting arrangement upon evaluation of fatigue strength and consideration of safety and redundancy provisions.

All critical fasteners and general purpose fasteners used to secure equipment to the locomotive, including truck and brake equipment bolts and all fasteners exposed to fatigue loads, shall be torqued to a minimum preload equal to 75 percent of their proof load and “torque sealed” or “torque striped” after torquing by paint or other approved means. All other fasteners shall be torqued to a value appropriate to the application, so that they do not loosen in service.

Fastener installation torque for standard oiled or waxed bolts with standard or heavy hex nuts may be calculated from Industrial Fasteners Institute, Fastener Standards, equations using values for “K” of 0.18 for un-plated and 0.15 for plated threads. Locknuts shall be torqued in accordance with their manufacturer’s recommendations or the Contractor may
conduct tests to determine installation torque. For those nuts or bolts requiring “torque striping”, SEPTA may require bolt torque-tension tests to verify that installed preload is equivalent to 75 percent of proof loads.

5. Critical Fasteners

All critical fasteners shall have documentation identifying manufacturer and purchase specifications available for examination by SEPTA at the Contractor’s QA department. This documentation shall include the fastener material or grade, and finish including plating material and specifications, when applicable. Whether the buyer is a sub-contractor, supplier, or the Contractor, the Contractor shall obtain and hold this documentation for a period of not less than termination of the last locomotive’s warranty period. After this period, all documentation shall be provided to SEPTA.

All critical fasteners shall either a) be manufactured, tested, and distributed in accordance with ASME FAP-1-1990, Quality Assurance Program Requirements for Fastener Manufacturers, Distributors and Testing Laboratories, including the requirements of ASME accreditation or b) have a representative sample of each production lot of fasteners tested for conformance to purchase specifications by an independent laboratory accredited by the American Association of Laboratory Accreditation (AALA), or approved equal. A production lot is defined as one size of fastener, from one manufacturer, produced during one continuous production run. Fasteners not meeting this definition of production lot shall be treated as separate lots. Testing shall be performed using sample quantities as proposed by the Contractor and approved by SEPTA. Tests conducted shall confirm that fastener material meets specified chemistry and strength requirements. The buyer shall obtain certified test results from the testing laboratory and hold the documents for a period of not less than the termination of the warranty period of the last locomotive. After this period, all documentation shall be provided to SEPTA.

All critical fasteners that are plated or chemically cleaned shall have certifications showing freedom from hydrogen embrittlement. Testing shall be done by the Contractor or a supplier following ASTM F519 procedures. An ASTM F606 wedge test sample may be used in place of the F519 standard samples. Test loads shall be a minimum of 80 percent of yield strength or proof load and held for a minimum of 168 hours. Any failures shall reject the entire lot.

15.3.2.4 General Purpose Fasteners

Mounting and attachment bolts shall be sized to the design strengths for Grade 2 bolts and Class A nuts, however in no case shall the fastener diameter be less than 0.375 inch. Grade 5 bolts and Class A nuts shall be used for installation of all equipment and/or structures.

Fasteners used within equipment shall meet all requirements of this Section other than the requirements specifically listed for critical fasteners or decorative fasteners, and shall be sized as appropriate for the application.
All general purpose fasteners shall have documentation that identifies the manufacturer, base material, plating or finish if applied, and the fastener type. The Contractor or supplier shall maintain this documentation on file for SEPTA to review for a period of not less than the expiration of the warranty on the last locomotive delivered. After this period, all documentation shall be provided to SEPTA.

Fasteners on access panels, plates, covers, or other components accessible by passengers shall be of a single style tamperproof type approved by SEPTA

All decorative and appearance fasteners shall have documentation that identifies the manufacturer, base material, plating or finish if applied, and the fastener type. The Contractor or supplier shall maintain this documentation on file for SEPTA to review for a period of not less than the expiration of the warranty on the last locomotive delivered. After this period, all documentation shall be provided to SEPTA.

15.3.3 Bonding

The joining of elastomeric pieces shall be conducted by the hot vulcanization process. Adhesive bonding of elastomers shall not be allowed.

All adhesive applications shall be approved by the manufacturer of the adhesive system and suitable for the materials being joined and the environmental exposure to be expected. Where adhesives are in contact with painted surfaces, suitable bond strength to both the paint and substrate shall be verified by test. The Contractor shall submit manufacturer’s data for all proposed adhesive applications prior to first use of the adhesive system.

15.3.4 Rivets and Lock Pins

Rivets and lock pins exposed to passengers or crew shall be austenitic stainless steel or aluminum, as appropriate to the materials being joined. Structural steel rivets shall conform to ASTM A 502 or American National Standard B 18.1.2 standards. Rivets may be hand driven when hot and shall completely fill the rivet holes. Rivets driven cold shall be mechanically driven. Exposed heads shall be concentric with the shank and free from rings, fins, pits, and burrs.

Swage-locking (Huckbolt type) fasteners shall conform to Military Specification MIL-P-23469. All rough surfaces of the collar end of these fasteners shall be machined or ground smooth where accessible to passengers, crew, or maintenance personnel performing routine maintenance functions. SEPTA shall be the final arbiter in determining whether an application is hazardous to maintenance personnel.

15.3.5 Rivet and Bolt Holes

Rivet and bolt holes shall be accurately located and aligned, and, when necessary during assembly, holes shall be reamed round to specified size in position. Bolt hole clearances shall not exceed the Industrial Fasteners Institute’s requirements. All removed and replaced rivets shall have the holes reamed to the size required such that the next larger rivet may be driven securely. Slotted holes may be used only where necessary and approved. Heavy flat washers shall be used at all slotted holes.
## 15.4 WELDING AND BRAZING

### 15.4.1 General

The Contractor shall be responsible for the quality of its welding and brazing as well as that of its suppliers and subcontractors. Cleaning prior to welding shall be in accordance with applicable parts of Section 2, MIL-HDBK-132, “Cleaning Materials and Processes.”

### 15.4.2 Structural


Structural welding of ferritic and austenitic stainless steel shall primarily be governed by AWS D1.6. ASME Section IX and ASME Section VIII, Part UHA shall apply where appropriate. 201L (UNS 20103) and 301LN (UNS 30153) stainless steels shall be treated as P-No. 8, Group-No. 3, category for reference to ASME requirements. Ferrite number for welds made with austenitic stainless filler materials shall be between WRC4 and WRC10, or as proposed by the Contractor and approved by SEPTA. Weld heat-affected zones (HAZ) and weld metal shall be limited to maximum allowable stress values in ASME Section VIII, Table UHA-23, for UNS S20100 stainless steel and Table UW-12 rating of welds. Fatigue allowable stresses shall not exceed the lesser of fatigue limits in AWS D1.1, Section 2.20.6, or 50 percent of the joint strength level calculated from ASME maximum allowable stress values. Higher values shall only be used if qualified by Contractor tests.

Regardless of the governing codes, all Welding Procedure Specifications (WPS) shall be fully qualified by test by the Contractor. Qualification shall be documented by Procedure Qualification Records (PQR). WPS and PQR shall be prepared by the Contractor and reviewed and accepted by SEPTA and a Certified Welding Inspector. The use of AWS-B2.1 guidelines for qualification shall not be permitted and shall not be included or referenced in WPS and PQR. The use of any WPS purchased from an outside agency shall not be permitted without separate qualification by the Contractor.

### 15.4.3 Welder Qualification

Welders shall make only those welds for which they have been qualified according to the requirements of the AWS, ASME Section IX, ASTM A488/A488M, or other approved qualifying procedures. AWS B2.1
“Standard for Welding Procedure and Performance Qualification”, may not be used for welder qualification. Records of welder qualification tests shall be made available for review.

15.4.4 Inspection of Welds

The Contractor shall visually inspect all structural welds in accordance with AWS D1.1 requirements.

In addition to the visual inspection specified for all welds, nondestructive surface inspection (dye penetrant or magnetic particle methods, as appropriate) shall also be used to inspect all first-production welds. The Contractor shall specify a sample nondestructive inspection rate for all subsequent welds.

If ring welds are used, on the first structure all ring welds shall be nondestructively inspected by magnetic particle or dye penetrant methods. The Contractor shall submit a random sampling plan for additional metallographic examinations of ring welds for approval. The minimum acceptable sampling plan shall require inspection of one (1) ring weld sample for every 300 production ring welds. A record of all NDT inspections shall be included in the Car History Book.

On the first structure, all full penetration welds shall be nondestructively, volumetrically inspected (ultrasonic or radiographic methods) according to AWS D1.1 requirements. The Contractor shall specify a random sampling plan for volumetric inspection of subsequent, full-penetration welds for approval. The minimum acceptable inspection plan shall require inspection of one (1) portion of a full penetration weld for every 200 production welds. The proposed test welds shall be selected from among welds that are most critically loaded as determined by calculation or load test. With approval, destructive sectioning and metallurgical examination may be substituted for some or all of the required volumetric inspection requirements for production welds.

15.4.5 Post-Weld Cleaning Requirements

All welds visible to passengers or on sliding contact surfaces of truck frames and bolsters shall be completely cleaned of spatter.

15.4.6 Contractor Documentation

All welding procedures and documents, including Welding Procedure Specifications, Procedure Qualification Records, and Resistance Spot Welding Schedules, shall be submitted for approval before application. Specifications for purchase of welding electrodes, welding wires, and cover gases shall be submitted for approval before their application.

15.4.7 Dissimilar Metal Welding

Procedures and qualification records for structural welding of stainless steel to LAHT shall be submitted for approval. As part of the qualification of all dissimilar metal welds, sample welds shall be sectioned and examined metallographically to determine HAZ hardness. The HAZ hardness shall not exceed 400 HV (Vickers Hardness).

Austenitic stainless steel electrodes or wire shall be used to join carbon or LAHT steels to stainless steels.
Galvanized steel shall not be welded to stainless steel.

15.4.8 Resistance Welding

Resistance welding of stainless or carbon steels shall be according to AMS-W-6858B, Class B for structural applications and Class C for non-structural applications. All resistance welding procedures shall be qualified per AMS-W-6858B; procedures and qualification records shall be submitted for review and approval. Contractor-proposed deviations from AMS-W-6858B, including, but not limited to, weld nugget diameter, tension shear strength, and minimum spacing, shall be submitted and approved before application in production.

Design strengths higher than standard certification and production strength requirements shall be qualified according to AMS-W-6858B, Figure 11b, for one (1) thickness combination. This shall require a test lot size of 180 spot welds. Additional thickness combinations with the same increased strength ratio may be qualified by twenty-five (25) spot weld shear tests plus three (3) macro-sections. Twenty (20) of the twenty-five (25) shear test specimens may be recorded from production witness tests taken from twenty (20) consecutive production days (not calendar days). The Contractor shall submit records of the settings, ultimate shear strength, weld diameter, and weld penetration for approval.

Surface indentation shall not exceed 20 percent of material thickness or 0.01 inch, whichever is greater. However, for exterior resistance-welded areas exposed to passenger view, indentation shall not exceed 10 percent of t or 0.005 inch, whichever is greater. For exposed welds, the Contractor shall vary welding parameters and conditions within their acceptable ranges to minimize indentations. Surface burn and discoloration shall be removed by chemical cleaning, or an approved equal method, and sanding or polishing to match the surrounding surface.

Production witness welds shall be made and tested once each day and, in addition, whenever otherwise necessary such as by change in any of the following:

- Operator
- Material, material thickness, or combination of thicknesses
- Electrodes
- Settings

15.4.9 Resistance Spot weld and Intermittent Weld Spacing

Spacing of resistance and spot welds shall be according to approved structural drawings. Spacing of welds contributing to carbody stiffness shall not exceed 2 inches plus twice the weld nugget diameter for any structural application, including carbody side sheets, roof sheets, and corrugation. For any application to corrugations, if the pitch of the corrugation nodes does not allow the above weld spacing, there shall be 2 spot welds between each node.
For intermittent fusion-welds contributing to carbody stiffness, spacing pitch shall not exceed 5 inches for 2 inch (minimum) weld lengths (40 percent minimum of length welded).

For structural members not contributing to carbody stiffness, the intermittent welds joining structural members contributing to the stiffness of other members must conform to the spacing criteria above. All other intermittent welds shall be designed and qualified in accordance with the appropriate welding code requirements.

15.4.10 Toughness of Welded Assemblies

The Contractor shall prove that all welded steel structures are above the ductile-brittle transition temperature for the specified environmental exposure. Specifically, the weld heat-affected zone (HAZ) and base metal shall resist service impact loads at the lowest specified operating temperature without brittle failure. In the absence of prior operating history, and if the Contractor’s approved design does not require greater toughness, the minimum impact value for Charpy V-notch specimens shall be 15 foot-pounds of absorbed energy at -20°F.

SEPTA shall have the right to require impact tests to verify the specified toughness. If tests are required, verification of HAZ toughness shall be done on a test sample welded according to PQR parameters. Base metal toughness shall be certified on a heat basis by the steel manufacturer or steel supplier; if these data are not available, the Contractor shall perform tests on each heat of as-received base metal.

Torch Brazing

All brazing, defined as heating above 840°F without base metal melting, shall follow the recommendations of the AWS Welding Handbook, Volume 2, latest issue. Procedures and personnel who perform brazing work shall be qualified in accordance with AWS B2.2, “Standard for Brazing Procedure and Performance Qualification”. Records of brazing procedure and performance qualification shall be submitted for approval.

15.4.11 Torch Soldering

All structural (not electrical) soldering, defined as heating below 840°F, shall follow the recommendations of the AWS Welding Handbook, Volume 2, latest issue. Procedures and personnel who perform torch soldering shall be qualified through the preparation and testing of samples of production torch soldering. Test samples shall be prepared and submitted for approval before production torch soldering.

15.5 STAINLESS STEEL

15.5.1 General

Permitted uses of structural stainless steels are specified throughout this Specification. Ferritic stainless steels shall be painted where exposed to passengers or the weather. Austenitic stainless steels may be unpainted. Unpainted stainless steels exposed to passengers shall be a single grade of austenitic stainless steel in which both the color and surface finish of abutting pieces shall match, except where the design specifically calls for contrasting appearance.
15.5.2 Austenitic Stainless Steel

Structural austenitic stainless steel components assembled by fusion or resistance welding shall be of AISI type 201L (UNS S20103), 301L (UNS S30103), 301LN (S30153) or JIS SUS301L (with Nitrogen) and shall conform to the requirements of ASTM A666 except that the carbon content shall not exceed 0.03 percent and type 301LN and SUS301L (with Nitrogen) shall not exceed 0.25 percent nitrogen. Other stainless steels conforming to ASTM A666 are acceptable for non-welded applications.

Stainless steel used in structural applications covered by this Specification shall also conform to APTA SS-C&S-004-98 Standard for Austenitic Stainless Steel for Railroad Passenger Equipment.

General requirements for delivery of stainless steel shall be as required by the Certification Provisions of ASTM A666. Stainless steel to be used in structural applications shall be tested for susceptibility to intergranular corrosion in accordance with ASTM A262, latest revision. Practice A of ASTM A262 can be used to accept material only; Practice E is required for final determination of acceptance or rejection of material that is not acceptable by Practice A.

15.5.3 Ferritic Stainless Steel

When specified, ferritic stainless steel conforming to ASTM A176 may be used for sheeting up to 0.2 inch thickness. Ferritic stainless steel sheet shall have a ductile-to-brittle transition temperature (DBTT) or nil-ductility temperature (NDT) below 0°F. Weld heat-affected-zones shall also have a DBTT or NDT below 0°F. Ferritic stainless steel sheet shall have a balanced composition (low carbon and/or suitable titanium content) that shall, for all conditions of fabrication and assembly into the locomotive body, inhibit formation of martensite and limit chromium depletion in weld-heat-affected zones so that material shall meet ASTM A763 requirements for resistance to intergranular corrosion.

General requirements for delivery of ferritic stainless steel shall be as required by ASTM A480.

Where ferritic stainless steels are welded to other structural steels, the less-noble steel shall be painted with weld-through primer.

15.5.4 Testing

The Contractor shall prepare (or have prepared), submit, and receive approval of a test and inspection plan for acceptance of all stainless steel to be used in welded applications prior to purchasing any such material. The tests and inspections shall verify that the stainless steel conforms to specified requirements. For austenitic stainless steels, the test and inspection plan shall include frequency of submittal of certifications in accordance with Certification Provision of ASTM A666 and frequency of submittal of checks for susceptibility to intergranular corrosion in accordance with ASTM A262. For ferritic stainless steels, the test and inspection plan shall include frequency of submittal of checks for susceptibility to intergranular corrosion in accordance with ASTM A763.
15.5.5 Flatness Tolerance

Coil stock shall meet standard mill flatness tolerances, unless otherwise specified. Sheet stock shall be of stretcher-leveled quality.

15.5.6 Finishing Methods

Unless otherwise specified, all smooth sheets exposed to passengers shall be given a medium-grit finish on the exposed side using a belt or oscillating sander. Grain shall be in a direction to suit the decorative treatment in the interior of the locomotive.

15.6 LOW-ALLOY HIGH-TENSILE STEEL

15.6.1 General

Low-alloy high-tensile (LAHT) steel structural shapes, plates, and bars shall, as a minimum, conform to the requirements of ASTM A588, where available. Plate steel may alternatively conform to ASTM A710; Grade A, Class 1, 2 or 3. Where not available in A588, hot rolled or formed structural shapes conforming to ASTM A36 may be used for limited applications including equipment supports and jack pads. General requirements for delivery of LAHT shapes, plates, and bars shall be as required by ASTM A6.

Cold and hot rolled LAHT sheet and strip shall, as a minimum, conform to the requirements of ASTM A606, Type 4. General requirements for delivery of these products shall be as required by ASTM A568.

Other low-alloy, high-tensile steels which meet or exceed the above minimum requirements may be used, provided their detailed specifications are submitted and approved as equivalent, or better material, for the proposed applications. All LAHT steels shall be applied according to their specification properties.

Welded LAHT steel shall develop 15 foot-pounds Charpy V Notch impact strength in the CGHAZ (Coarse grain heat affected zone) 0.03937 inches from the fusion area at -20°F.

15.6.2 Testing

The Contractor shall prepare (or have prepared), submit, and receive approval of a test and inspection plan for acceptance of all structural steels in accordance with the requirements of this Section before purchasing any such material. The test and inspection plan shall include provisions for submission of reports and certification to SEPTA for each shipment in accordance with the applicable requirements of the purchase specification and specified CGHAZ impact tests.
15.7 STEEL CASTINGS

15.7.1 General

The Contractor shall be responsible for selecting casting grade, composition, strength, and finishing. However, steel castings, used in the carbody structure and truck assemblies shall meet AAR Specification M-201 latest revision, Grade “B”, plus two percent nickel, minimum. These 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 25 percent in 2-inches, and reduction of area of not less than 50 percent. Also, steel castings used for coupler, drawbars, and anchors shall meet AAR Specification M-201, latest revision, Grade “C” or “E”, quenched and tempered.

Where cast steel of superior properties is required for a specific application, the Contractor may propose such castings for review and approval of SEPTA.

Stainless steel composition and processing must be selected such that the castings shall be able to meet or exceed the strength required by the specified application, as determined by SEPTA. Stainless steel castings shall be made in accordance with appropriate ASTM standard(s), depending on the type of stainless steel used. Other standards may be used upon SEPTA approval.

15.7.2 Design Qualification of Structural Castings

One steel casting, selected by SEPTA from the first lot of production steel castings, shall be subjected to a qualification test of the casting design by the Contractor. A statistical sample of stainless steel castings, as agreed upon by SEPTA and the Contractor, from the first lot of production stainless steel castings, shall be subjected to a qualification test of the casting design by the Contractor. Qualification tests shall include radiographic examination for material soundness using reference radiographs to ASTM E 446 and any mechanical testing.

Acceptance levels for the design qualification radiographic examinations shall be selected by the Contractor as appropriate for the service intended, subject to the approval by SEPTA before any castings are produced. Radiographs shall meet the requirements of ANSI/ASTM E 94 and E 142 for steel castings, and ASTM E 1742 for stainless steel castings, and the quality level in the area of inspection shall be at least two percent (2-2T).

A qualification test report shall be prepared and submitted to SEPTA for approval. The production of any castings before receipt of SEPTA’s approval of this report shall be at the Contractor’s risk. All radiographs from the qualification test shall be made available to SEPTA for review. If the casting selected for qualification fails to qualify, a plan of action, including details of how failed material shall be handled, shall be included in the qualification test report. Once a design is qualified and accepted by SEPTA, no changes shall be made in the casting pattern, technique, heat treatment, or material composition without requalification in accordance with the requirements of this Section.
15.7.3 Quality of Structural Castings

All structural castings supplied shall be equal to or better than the design qualification castings in all respects. The casting supplier or Contractor shall test, inspect, and accept castings in accordance with procedures described in AAR Specification M-201 for steel castings. For stainless steel castings, the procedures shall be proposed by the Contractor and approved by SEPTA. In addition, the inspections below, as applicable, shall be performed and a written report of the results of the tests and inspections shall be furnished for each lot of castings produced.

1. Magnetic Particle Inspection
   Magnetic particle inspections of all surfaces of each casting shall be conducted, according to ASTM E 709, by personnel certified to MIL-STD-410. With respect to structural castings, including coupler castings, the maximum permissible magnetic particle indications shall be not more than ¼-inch in the direction transverse to the usual direction of loading, and no more than ¾-inch in the direction parallel to the usual direction of loading.

   For martensitic and ferritic stainless steel castings, acceptance criteria shall be in accordance with ASTM A 903.

2. Radiographic Inspection
   Radiographic inspection of steel castings shall be conducted according to the requirements of ASTM Standards E 94 and E 142, using reference radiographs to ASTM E 446. Radiographic inspection of stainless steel shall be conducted according to the requirements of ASTM Standards E 94, E 1742 and E 1030. A sampling frequency shall be proposed by the Contractor and submitted for approval by SEPTA.

   Structural castings shall not exceed severity level 3 of ASTM E 446 in all critical areas of such castings and shall not exceed level 5 in all other areas of the castings. During demonstration that the stated severity level requirements of ASTM E 446 have been met, successively produced castings shall be re-inspected by radiography in the defective areas shown in the prior radiographic inspection. After such severity levels have been proved, the sampling frequency for structural castings shall be one casting out of each 10 produced. If no castings are rejected by radiographic inspection, this frequency may be extended to one casting in 25.

3. Liquid Penetrant Inspection
   For non-magnetic stainless steel castings, liquid penetrant inspections of all surfaces of each casting shall be conducted according to ASTM E 165, by personnel certified to MIL-STD-410. Acceptance criteria shall be established in accordance with ASTM A903.

15.7.4 Repair Welding and Cast-Weld Design

Repair welding of steel castings is permitted, provided the casting supplier performs all repair welds according to the structural welding requirements of this Specification. Castings requiring repair or modification by welding after completion of heat treatment may be stress relieved locally by using electrically-controlled heating to a temperature not greater than 1150°F and slow cooling. Manual torch stress relief shall not be permitted except for cosmetic welds and only then after the procedures have been submitted for review and approval. For cast-weld designs, the entire length of all assembly welds...
on any welded assembly of several separate castings selected for design qualification shall be radiographically inspected to ANSI/ASTM E 94 and E 142, using reference radiographs from the International Institute of Welding’s “Collection of Reference Radiographs of Welds,” quality level Green. Portions of assembly welds stressed in tension by service loads shall meet quality level Blue.

No repair welding of stainless steel castings is permitted without express written approval of SEPTA.

**15.7.5 Disposal of Non-Conforming Castings**

If castings are found to be non-conforming to requirements determined by the design qualification castings, the material shall be repaired, retested, and reinspected or destroyed at the Contractor’s expense.

**15.8 ALUMINUM**

**15.8.1 General**

Aluminum alloy mill products shall be identified by Unified Numbering System designations and shall conform to The Aluminum Association specifications contained in the Association’s publication “Aluminum Standards and Data”. Aluminum alloy castings shall conform to ASTM B26, B85, or B108 for, respectively, sand, die, or permanent mold castings. Aluminum alloy forgings shall conform to ASTM B247. Copies of all test reports for sheet, extrusion, and forgings used in the locomotive structure shall be submitted to SEPTA.

**15.8.2 Fabrication and Fastening**

The forming of aluminum parts; joining of parts by bolting, riveting, and welding; and the protection of contact surfaces shall, as a minimum, conform to the requirements of the Aluminum Company of America’s Technical Report No. 524, “Specification Covering Use of Aluminum in Passenger Carrying Railway Vehicles”, except as otherwise specified herein.

Fabrication techniques shall be such that the strength and corrosion resistance of the aluminum shall not be impaired nor the surface finish permanently marred or discolored during construction.

**15.8.3 Protection of Contact Surfaces**

The specific measures to be taken by the Contractor to prevent the risk of direct metal-to-metal contact and resultant possible electrolytic corrosion shall be approved and shall depend upon the determination of the most suitable method which can be adapted to the design involved. The following instructions shall be the minimum protection.

- Aluminum alloy surfaces shall not be secured to or make direct contact with the surfaces of copper, copper bearing aluminum alloy, brass, bronze, silver, nickel, nickel alloys, nickel plated parts, lead, tin, or wood.
• The contact surfaces of aluminum alloy with aluminum alloy shall be painted with zinc chromate primer or approved equal before securing.

• The surfaces of aluminum alloy parts secured to steel parts, where exposed to weathering or harsh environments, shall be protected with a one-part polysulphide sealant, zinc chromate paste, mica insulation joint material, or an approved equivalent material which completely covers the faying surfaces. The insulating material shall be non-hygroscopic and, if fibrous, shall be impregnated with bitumen or an approved, non-corrosive, water and moisture-repellant substance. After driving, fasteners shall be primed and painted with red oxide or aluminum paint.

• Stainless steel and carbon steel fasteners plated with zinc shall be coated with zinc chromate paste or approved equal before installation. Where possible, only the head and the shank of the bolt shall be in contact with the aluminum part when secured in place. Suitable bushings may be used in place of the zinc-chromate paste.

15.8.4 Interior Trim

Where unpainted aluminum is exposed to contact by personnel, it shall have a clear (natural) anodic finish. The finish process shall be the Aluminum Company of America’s “Alumilite 204” with a minimum coating thickness of 0.0004 inch and a minimum coating weight of 21 milligrams per square inch, or approved equal process.

15.9 ELASTOMERS

15.9.1 General

Elastomers shall be compounded and cured to perform as intended in the environment specified in Section 2. Elastomers shall have high resistance to ultraviolet and other solar radiation, weather and to all SEPTA car-washing and cleaning fluids. All elastomeric parts shall be resistant to ozone, oxidation, heat, oil, grease and acid, and shall have the longest possible life, consistent with the other characteristics specified.

The following elastomeric parts shall be of an applicable compound unless otherwise specified or approved:

• Glazing Rubber,

• Door Seals,

• Door Nosing,

• Other parts exposed to the outdoor ambient environment, except where otherwise specified.

• The following elastomeric parts shall be of natural rubber, (synthetic rubber compounds are not permitted) unless otherwise specified or approved:
• All resilient mounts,

• Elastomeric truck components.

Elastomers used within pneumatic or hydraulic equipment shall be as necessary to meet the performance requirements of this specification for the pneumatic or hydraulic device.

All elastomeric parts are to be marked with the date of manufacture and shall not have aged more than 12 months when assembled into the locomotive.

15.9.2 Life Expectancy

For all parts made by vulcanizing an elastomer to metal, any premature failure (less than six years) between metal and the elastomer or in the elastomer, occurring when the parts are used in normal service and according to the provisions of this Specification, shall be considered as having been caused by defect of materials or workmanship.

15.9.3 Metal Parts

Metal parts to which elastomeric material is vulcanized shall be made of SAE 1020 or 1045 hot-rolled steel.

15.9.4 Truck Parts

Truck bumpers, snubbers, and the exterior surfaces of air springs shall be made of natural rubber or approved equal. They shall be compounded to be resistant to abrasion, oil, grease, and acid.

15.9.5 Seals

Glazing strips shall be of neoprene conforming to ASTM C542, or approved equal material.

All door mating edges, door and window seals, and glazing strips shall be of neoprene material. The durometer hardness measured with a Shore Type “A” durometer at a temperature between 70°F to 90°F shall be 70 ±5 except for the side door mating edges where it shall be 80 ± 5.

15.9.6 Bonding

The joining of elastomeric pieces shall be conducted by the hot vulcanization process. Bonding of elastomers by other processes shall not be allowed unless the Contractor submits the application, bonding procedure and bonding agent technical data for approval prior to the purchase of any materials.

15.9.7 Tests

All tests shall be conducted according to the latest revisions of the specified ASTM test procedures, unless otherwise specified, and the results of the testing shall be submitted to SEPTA.
The test specimens shall be cut out 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 order. If the compound or cure, or both, are changed during the production of material for one order, at least one test of each type shall be made for each different batch.

When testing the 6 inch by 0.50 inch ASTM "dumb bell" type test specimen (or smaller size if the size of the part necessitates) by the methods specified in ASTM D3182, D3183, D3190, and D412, the tensile strength shall not be less than 1,500 psi and elongation shall be a minimum 350 percent. The tensile strength of the elastomer shall not be reduced more than 25 percent when subjected to accelerated aging by the methods specified in ASTM D573, for a period of 96 hours in an air oven at 158°F.

The ozone resistance of the elastomer shall be tested in accordance with ASTM D1149 using an ozone concentration of 100 pphm, an exposure time of 100 hours at 100°F, and a specimen elongation of 20 percent. The elastomer shall not exhibit any cracks during the test period.

All elastomers shall be also tested according to the Flammability, Smoke Emission, and Toxicity section of this Specification.

### 15.10 GLAZING MATERIALS

#### 15.10.1 Safety Glass

Safety glass shall meet the requirements under Item 1, Table 1 of ANSI Z26.1, "American National Standard for Safety Glazing Materials for Glazing Motor Vehicles and Motor Vehicle Equipment Operating on Land Highways - Safety Code" and FRA 49 CFR 223 Type I or II test as appropriate for the application.

##### 15.10.1.1 Type

All safety glass shall be of the laminated sheet type.

##### 15.10.1.2 Flatness

When an individual light of glass is laid on a truly flat surface, such as a surface plate, the glass shall not indicate a bow of more than 0.030 inch per linear foot.

##### 15.10.1.3 Dimensional Tolerance

The overall dimensions of individual lights as supplied shall be held within 0.060 inch of the dimensions ordered.
15.10.1.4 Overlap Tolerance

The overlap of one laminate of the light with respect to the other at an edge shall not exceed 1/32 inch. Corners and burrs shall be ground smooth and all edges shall be treated in accordance with ANSI Z26.1, Section 6.

15.10.1.5 Color

The color of the glass shall be as specified. When new, there shall be no more than ± 4% variation in the color of individual lights of laminated sheet glass when examined over a white background.

15.10.1.6 Haze

All the laminates of the safety glass shall be so nearly free from haze that the glass shall have approximately the same clarity as a light of the same nominal thickness of plate glass when viewed against a north light.

15.10.1.7 Specks and Scratches

Occasional specks of foreign material and scratches are permissible, provided such specks do not exceed 0.020 inch in greatest dimension and scratches do not exceed a total of 3 inches in length and neither are within the central three-quarters area of the light.

15.10.1.8 Bond Separation

The bond between two sheets of glass and the membrane shall be of such quality that when the glass is broken by twisting or by direct impact, there shall be no separation between the glass sheets. Lights that contain un-bonded areas shall not be used.

15.10.1.9 Marking

Each light shall be marked for identification by the supplier in legible letters 0.1 inch high in the lower right hand corner as viewed from the inside of the vehicle. This identification shall be no closer than 3/4 inch to the edge. The identification shall give the product name, the manufacturer, the serial number, and FRA Type designation. Markings shall be legible and permanent for this application and shall be applied in such a manner so as not to reduce the integrity of the material. Markings are to be in accordance with ANSI standard Z26.1 and 49 CFR Part 223. The light shall be installed so that the identification can be read from the inside.

15.10.1.10 Quality Assurance

The Contractor shall be responsible for the performance of all inspection and test requirements. Except as otherwise specified, the Contractor may utilize the facilities of its supplier or any approved commercial laboratory.
15.10.11 Shipping
The material shall be carefully prepared for shipping and shall be properly protected to prevent damage. If a pressure sensitive masking is used, it shall be easily stripped from the material and not leave a gummy or sticky residue.

15.10.12 Documentation
The Contractor shall certify that the shipped material complies with the requirements in this Specification.

15.10.2 Plastic Glazing

15.10.2.1 General

15.10.2.2 Applicable Documents
The latest issue of the following documents, in addition to those specified in this Section, shall form a part of the Specification:

- ASTM G 23 – Recommended Practice for Operating Light – and Water – Exposure Apparatus (Carbon Arc Type) for Exposure of Nonmetallic Materials.
- ASTM D 1499 – Recommended Practice for Operating Light – and Water – Exposure Apparatus (Carbon Arc Type) for Exposure of Plastics.
- ASTM D 1003 – Recommended Practice for Determining Haze Factor.
- ASTM E 162 – Radiant Panel Test For Determining Flame Propagation Index (Is).
- ASTM E 662 – Test to Determine Smoke Emission Values (Ds).
15.10.2.3  Strength

Samples shall be prepared and tested according to 49 CFR 223 and 238 and Test Number 10, Article 5.10, of ANSI Standard Z26.1. Samples shall not shatter or break when subjected to the falling dart impact requirements of Test Number 10. The dart tip shall be no more than 0.50-inch radius. Denting or marring of the surface of the tested piece in this test is permissible.

15.10.2.4  Light Transmission

Visible light transmission through clear plastic glazing shall not be less than 85% in 0.125-inch thickness, 82% in 0.250-inch thickness, 80% in 0.375-inch thickness, and 78% in 0.5-inch thickness.

Visible light transmission through tinted plastic glazing shall be as specified.

15.10.2.5  Weathering Test

The materials shall pass the long arc Xenon lamp-weathering test Number 16 of ANSI Standard Z26.1.

15.10.2.6  Color

The color of the plastic glazing shall be as specified. The material shall be integrally colored and shall have UV stabilizer additives to inhibit fading and loss of properties due to extended exposure to direct sunlight. When new, there shall be no more than 4% variation in the color between lights of plastic material of a specified color and thickness, when examined over a white background, and measured by the appropriate light transmission or color meter inspection and test instruments.

15.10.2.7  Abrasion Resistance

Plastic glazing materials shall be silicone-coated on both sides to increase resistance to abrasion. The coated plastic shall meet the following specifications:

- Property
- Test Method
- Requirements
- Abrasion Resistance
- ANSI Z26.1 Test 17
- The change in percent haze after 100 cycles shall be less than six

The glazing material supplier is required to perform the following test prior to qualification: The plastic glazing material after 300 hours of weatherometer testing shall pass abrasion resistance ANSI Z26.1 Section 5.17. The foregoing test is to be performed for initial product certification.

15.10.2.8  Chemical Resistance

Samples shall be prepared and tested according to Test 19, Article 5.19, of ANSI Z26.1. The exposed fabricated edges of the test samples may be coated with the same material as the face surfaces by the manufacturer. In addition to those chemicals specified in this test, the test shall also include, but not be
limited to, such cleaning solutions as used by SEPTA for cleaning locomotives. The exposure time of the test shall be increased to one-hour intimate contact with the test chemicals on the faces of the test sample. The contaminants shall be either wiped or sprayed onto the coated faces of the test sample. Any tackiness, crazing or apparent loss of transparency shall be cause for rejection. After immersion, a change in percent haze greater than five, as measured by Test 17 on ANSI Z26.1, shall be cause for rejection.

15.10.2.9 Adhesion of the Coating Materials

The abrasion resistant coating materials shall retain adhesion to the substrate materials when subjected to Test Number 10, Article 5.10, of ANSI Standard Z26.1. The coating shall also pass a standard cross cut adhesion test. This test consists of scribing a grid of four horizontal and four vertical 1-inch long lines through the coating with a sharp steel blade. Pressure sensitive tape, Scotch brand Number 335-2, is then pressed firmly over the scribed area and is then pulled away at 90 degree angle to the sample sheet. The coating shall pass the test if no coating is removed from the substrate material.

There shall be no detectable cracking of the coating as indicated by fine radial cracks at the point of impact when struck with 2½ ft.-lb. energy from a dart having a ½-inch radius tip. The impacted specimen shall be examined for radial cracks visible by transmitted light.

No detectable cracks in the coating shall develop when the specimen is strained 2%. Stress may be applied by imposing 6,000 psi loading, using a tensile testing machine.

15.10.2.10 Dimensional Tolerance

The overall dimensions of individual units as supplied shall be within 0.030-inch of the nominal dimension specified. The thickness of the plastic materials shall be within a tolerance of + 5% of the nominal thickness.

15.10.2.11 Flatness

When an individual light is placed on a truly flat surface, such as a surface plate, the material shall not indicate a bow of more than 0.031-inch per linear foot in any direction.

15.10.2.12 Edge Work

All edges shall be straight and perpendicular to the surface, and shall be sawed or routed and reasonably free of burrs in order to prevent cutting of the rubber glazing strips. Sharp corners shall be removed around the entire periphery.

15.10.2.13 Optical Quality

Optical quality of the plastic glazing materials shall be in accordance with Test Number 15, Article 5.15.2.2, of ANSI Z26.1. Under the specified procedure, no light and dark patches, existent over the entire area, shall appear in the shadow of the unmasked area of the specimen before the specimen shall have been moved a distance of at least 14-inches from the screen.
Protective covering or other means shall be marked to permit orientation of extrusion grain for most favorable results at installation. This extrusion grain axis shall be horizontal in the installed light.

### 15.10.2.14 Material Quality

1. **Foreign Material and Inclusion Defects**
   - Less than 0.009-inch – allowed without population limit to the extent that they do not constitute a severe defect such as clustering.
   - 0.010-inch to 0.019-inch – allowed up to 10 per square foot average over the area of the light.
   - 0.020-inch to 0.050-inch – allowed up to three per square foot average over the area of the light.
   - 0.051-inch to 0.065-inch – allowed one per square foot average over the area of the light.
   - 0.066-inch to 0.150-inch – allowed one per edge, only in the outer 25% of the light.
   - 0.151-inch and above – shall be cause for rejection.

   Note: There shall be no black speck clusters of three or more above 0.019-inch in a 1-inch diameter circle.

   Defects occurring in those areas of the lights which shall be covered by the glazing strips shall not be cause for rejection.

2. **Fibers and Scratches**
   - Fibers and scratches less than 0.060-inch in length are allowable without population limit to the extent that they do not constitute a severe defect such as clustering.
   - Fibers and scratches from 0.060-inch to 0.125-inch in length are allowed up to a maximum of two per square foot average over the area of the light.
   - Fibers and scratches from 0.126-inch to 0.250-inch in length are allowed up to a maximum of one per square foot average over the area of the light.
   - Fibers and scratches greater than 0.250-inch in length are not allowed.

   Fine scratches which are detectable only when viewed in bright back lighting are acceptable.

3. **Bubbles**
   - There shall be no clusters of bubbles, no chain bubbles and no bubbles larger than 0.030-inches in diameter.
Bubbles 0.020-inch to 0.030-inch in diameter, if present, shall have a minimum separation of 3-inches.

In any 2-inch diameter area of glazing material, there shall be a maximum of 4 bubbles in the 0.011-inch to 0.020-inch diameter range.

18.10.2.14.4 Apparent Runs
0.125-inch and under – allowed without population limit to the extent that they do not constitute a severe defect such as clustering.

0.126-inch to 0.250-inch – allow four per square foot average over areas of light but not to the extent that they constitute a severe defect.

0.251-inch to 0.500-inch – allow one per square foot, providing it does not constitute a severe defect.

0.501-inch to 1.00-inch – allow one per edge only in the outer 25% of light area.

1.01-inch or above – shall be cause for rejection.

4. Orange Peel
“Orange Peel” in the surface shall be cause for rejection of the material if it exceeds the standards to be established between the Contractor and SEPTA prior to manufacture.

18.10.2.15 Quality Assurance

The Contractor shall be responsible for the performance of all inspection and test requirements. Except as otherwise specified, the Contractor may utilize the facilities of its supplier or any approved commercial laboratory.

18.10.2.16 Shipping

The material shall be carefully prepared for shipping and shall be properly protected to prevent damage. If a pressure sensitive masking is used, it shall be easily stripped from the material and not leave a gummy or sticky residue.

18.10.2.17 Identification

Each light shall be marked for identification in accordance with the requirements of ANSI Z26.1, Section 7 and 49 CFR 223 by the supplier in legible letters 0.1-inch high in the lower right hand corner as viewed from the inside of the vehicle. This identification shall be no closer than ¾-inch to the edge. The identification shall give the product name, the manufacturer, the serial number, and FRA Type I or II designation. Marking shall be legible and permanent for this application and shall be applied in such a manner so as not to reduce the integrity of the coating. The light shall be installed so that the marking can be read from the inside.

The protective covering or other means shall be clearly marked with at least 1 inch high letters "THIS SIDE OUT" to indicate correct application of glazing with respect to protective coating. Location of these markings must be visible for identification after installation.
5. Documentation
   The Contractor shall certify that the shipped material complies with the requirements in the Specification.

### 15.11 PANELS

#### 15.11.1 Phenolic Composite Floor Panels

Phenolic composite floor panels shall be designed to withstand the following physical requirements with no visible or audible indications of delamination of the panel skin from the core, and permanent deformation of the top surface shall be less than 0.010-inch unless otherwise specified. There shall be no puncture or damage to fibers of the top surface. There shall be no separation of any internal core from the top or bottom skin. There shall be no fracture of the core. All test results are required to be submitted to SEPTA for approval.

- **Indentation Resistance** – The floor panel shall withstand a concentrated load of 300 pounds applied to a test dowel that has an overall 0.375-square inch surface area, with a 0.0625-inch radius on bottom edge of test dowel.

- **Static Load Test – Average Loading** – A representative sample section of the flooring (without rubber floor covering attached) shall be supported on beams spaced at the maximum spacing used on the locomotive using production bonding and fastening techniques. A uniformly distributed load approved by SEPTA shall be applied to both sides of the joint (butt and/or shiplap). There shall be less than 0.088-inch deflection.

- **Static Load Test – Maximum Loading** – Using the identical floor panel-mounting configuration as described above, a uniformly distributed load of 200 lb. /ft² shall be applied to both sides of the joint (butt or shiplap).

- **Small Area Static Load Test** – Using the identical floor panel mounting configuration as described above, a 300 pound load shall be applied to a 1-inch x 3-inch contact area directly over the mid-span, 6-inches from the outer carbody sidewall edge. The footprint shall be machined flat within 0.010-inch and the edges shall have a radius of not more than 0.125-inch. There shall be less than 0.200-inch deflection as a result of the load applied.

- **Small Object Impact Test** – Using the identical floor panel mounting configuration as described above, a 16-pound standard bowling ball shall be raised directly over the mid-span, 24-inches from the edge of the panel and dropped from height of 60-inches. Permanent deformation of the top surface shall be less than 0.063-inch. Some core damage and some skin separation, radiating outward in a circular pattern with a maximum radius of 6.5-inches from the center of impact shall be allowed.

- **Large Object Impact Test** – Using the identical floor panel mounting configuration as described above, a 150-pound load shall be dropped from a height of 12-inches upon a 3-inch x 8-inch contact “footprint” pad located directly over the mid-span, 24-inches from the edge of the panel. The “footprint” pad shall have a rubber pad on the downside surface with a Shore D 70
minimum. The pad shall have a 1-inch thickness machined flat within 0.060-inch with edges having a radius of not more than 0.030-inch. Permanent deformation of the top surface shall be less than 0.030-inch. Some core damage and some skin separation shall be allowed in a 6.5-inch diameter area.

- Rolling Load Test – Using the identical floor panel mounting configuration as described above, a four-wheeled cart with a load of 200 pounds per wheel shall be rolled on the panels laterally, longitudinally and in a circular path with a 2-foot radius. The wheels shall be 3-inches in diameter, 1-inch wide with a 0.125-inch radius on each edge with a Shore A durometer of 80.

15.12 NOT USED

15.13 FIBERGLASS-REINFORCED PLASTIC

15.13.1 General
Fiberglass-reinforced plastic (FRP) shall be a laminated material, consisting of a gel coated surface and a combination of reinforced fibers in a thermoset polymer resin matrix, where the reinforcement has an aspect ratio that enables the transfer of load between fibers, and the fibers are chemically bonded to the resin. FRP shall withstand, without any physical deformation or structural damage, the environmental conditions in Section 2, and be resistant to acids, alkalies, and cleaning solutions recommended by the Contractor or used by SEPTA.

FRP shall be manufactured by an open molding or matched die molding process. Production techniques shall ensure that the glass fiber reinforcement is uniformly distributed throughout the final product in such a manner as to avoid resin-rich or resin-starved sections. An analysis shall be performed to confirm that the proposed construction method, glass content and laminate structure is adequate for its intended purpose and meets the strength requirements provided in the Specification. If Tedlar is applied to exposed interior surfaces, it shall be applied using the in-mold process.

FRP parts shall have a minimum thickness of 0.125 inch and shall have a greater thickness at attachment points and edges. If fasteners are used to attach and/or assemble FRP parts, the parts shall be reinforced in a manner approved by SEPTA to preclude the development of cracks. Exposed sharp edges shall not be allowed on any parts.

15.13.2 Construction

15.13.2.1 Resin
The resin shall be of good commercial grade, thermosetting, polyester, phenolic, vinyl-ester, or acrylic material selected to meet the physical properties of the Specification and molding process requirements.
15.13.2.2 Reinforcement

The fiberglass reinforcement shall be mat, fabric, woven roving, continuous roving, spun roving, or swirl mat as required to meet the physical properties of the Specification and the molding process requirements. The proposed glass content shall be a minimum 20% by weight, and shall be confirmed through testing to ASTM D 2584.

15.13.2.3 Gel Coat

A gel coat shall be provided on all finished surfaces of FRP. The gel coat shall be resistant to scuffing, fire, weather, and cleaning agents. The gel coat shall have a minimum thickness of 0.016-inch and a maximum thickness of 0.030-inch. If the surface of the FRP panel is to be painted, a primer gel coat shall be used and the part shall be painted in accordance with the Specification. If the FRP panel does not receive paint, then the gel coat shall be pigmented to match the color scheme selected by SEPTA.

Finished gel coated surfaces shall have a minimum gloss value of 85 when measured with a 60° glossometer and shall exhibit no print through of the reinforcements or have any appreciable orange peel.

15.13.2.4 Additives

Additives, fillers, monomers, catalysts, activators, pigments, fire retardants, and smoke inhibitors shall be added to the resin mixes to obtain finished products with the required physical, flammability, and smoke emissions characteristics of the Specification.

Antimony trioxide is prohibited as a component.

15.13.3 Strength Requirements

Independent laboratory test reports of production items shall be provided confirming that the production reinforced plastic material complies with the requirements of the following standards. The sample tested must be from a final production part and not simply the base laminate material. Test specimens shall be conditioned in accordance with ASTM D 618.

<table>
<thead>
<tr>
<th>Mechanical Property</th>
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<th>Class II</th>
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<tr>
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<td></td>
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<td>45 Barcol</td>
</tr>
</tbody>
</table>

Class I: Items which are non-structural or shall not be exposed to any loads such as window masks, destination sign shrouds, ceiling cove panels, ceiling headers, etc.
Class II: Items which are structural or shall be exposed to loads from crew or impacts such as end bonnets, under floor equipment enclosures, door pocket panels, wainscot panels, toilet room modules, toilet shrouds, seat back shrouds, windscreens, stair wells, etc.

15.14  SEAT CUSHION

15.14.1  General
Cab seat cushion fill material shall be low-smoke flexible foam constructed of inherently fire-retardant materials. The thickness shall be subject to approval during design review. The material shall have a polymerized or vulcanized homogeneous (free from foreign material) cellular structure with a porous surface and open cells. The cells shall be interconnecting and uniform in size. Cellular material may be molded in one piece or may be assembled by laminating to achieve the required thickness. Laminated cushions shall be bonded together. Cushion material shall be properly cured to prevent any objectionable odor.

15.14.2  Physical Properties

15.14.2.1  Non-Silicone Foam
Non-silicone flexible low smoke foam shall meet the following physical property criteria when tested without upholstery material:

- Tensile Strength – 12.0 lbf/in² minimum when tested to ASTM D 3574 Test E
- Elongation – 150 percent minimum when tested according to ASTM D 3574 Test E
- Compression Set at 50 percent – A maximum of 10 percent when tested according to ASTM D 1055
- Flex Fatigue – Thickness loss 5 percent maximum when tested according to ASTM D 1055
- Tear Strength – 2.0 lbf/in² minimum when tested according to ASTM D 3574

15.14.2.2  Silicone Foam
Silicone foam shall meet the following physical property criteria when tested without upholstery material:

- Tensile Strength – 15 lbs./in² minimum when tested to ASTM D 3574 Test E
- Elongation – 100 percent minimum when tested according to ASTM D 3574 Test E
• Compression Set at 50 percent – A maximum of 10 percent when tested according to ASTM D 1056

• Flex Fatigue – Thickness loss of 5 percent maximum when tested according to ASTM D 1055

• Tear Strength – 2.0 lbf/in² minimum when tested according to ASTM D 3574

15.15 SEAT UPHOLSTERY MATERIAL

15.15.1 Cloth Fabrics or Leather

15.15.1.1 General
Where specified or permitted, cloth fabrics used for seat upholstery shall be made of woven, transportation grade fabrics of wool, wool/nylon blend (90/10, 85/15), or an approved flame-resistant polyester. The maximum fabric shrinkage shall be 2 percent in either the warp or fill direction.

15.15.1.2 Physical Properties

1. Wool/Nylon Blend
Wool/nylon blend seat upholstery material shall be subjected to the physical tests of textile products required by the latest revision of the following ASTM methods, and the results shall not be less than the following values:

<table>
<thead>
<tr>
<th>Test Number</th>
<th>Description</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>D-3776</td>
<td>Fabric Weight</td>
<td>15.5 oz/sq yd without back coating</td>
</tr>
<tr>
<td>D-3775</td>
<td>Fabric Count</td>
<td>Warp – (ends) 88 epi Fill – (picks) 40 to 72 ppi</td>
</tr>
<tr>
<td>D-5034</td>
<td>Breaking Strength and Elongation</td>
<td>Warp – 200 lbs Fill – 200 lbs</td>
</tr>
<tr>
<td>D-2261</td>
<td>Tear Strength (Tongue)</td>
<td>Warp – 20 lbs Fill – 20 lbs</td>
</tr>
<tr>
<td>D-4034</td>
<td>Yarn Slippage</td>
<td>Warp – 30 lbs Fill – 40 lbs</td>
</tr>
<tr>
<td>D-3597</td>
<td>Color Fastness</td>
<td>Water – Class 4 minimum Solvent – Class 4 minimum Crocking – Class 4 minimum Light – Class 4 minimum</td>
</tr>
<tr>
<td>D-4966</td>
<td>Martindale Abrasion Test</td>
<td>20,000 cycles – no breaks</td>
</tr>
</tbody>
</table>

2. Polyester
Flame-resistant polyester seat upholstery material shall be subjected to the physical tests of textile products required by the following ASTM methods, and the results shall not be less than the following values:
### Materials and Workmanship

#### Section 15

<table>
<thead>
<tr>
<th>Test Number</th>
<th>Description</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>D-3776</td>
<td>Fabric Weight</td>
<td>12 oz/sq yd without back coating</td>
</tr>
<tr>
<td>D-3775</td>
<td>Fabric Count</td>
<td>Warp – (ends) 88 epi</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fill – (picks) 40 to 72 ppi</td>
</tr>
<tr>
<td>D-5034</td>
<td>Breaking Strength and</td>
<td>Warp – 270 lbs</td>
</tr>
<tr>
<td></td>
<td>Elongation</td>
<td>Fill – 200 lbs</td>
</tr>
<tr>
<td>D-2261</td>
<td>Tear Strength (Tongue)</td>
<td>Warp – 20 lbs</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fill – 20 lbs</td>
</tr>
<tr>
<td>D-4034</td>
<td>Yarn Slippage</td>
<td>Warp – 75 lbs</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fill – 65 lbs</td>
</tr>
<tr>
<td>D-3597</td>
<td>Color Fastness</td>
<td>Water – Class 4 minimum</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Solvent – Class 4 minimum</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Crocking – Class 4 minimum</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Light – Class 4 minimum</td>
</tr>
<tr>
<td>D-4966</td>
<td>Martindale Abrasion Test</td>
<td>20,000 cycles – no breaks</td>
</tr>
</tbody>
</table>

#### 3. Fabric-Backed Vinyl

a. **General**

Where specified or permitted, vinyl used for seat upholstery shall be made of woven transportation grade fabric-backed vinyl with a minimum weight of 22.75 ounces per square yard.

b. **Physical Properties**

Fabric-backed vinyl used for seat upholstery shall be subjected to the physical tests of textile products required by ASTM and the results shall not be less than the following values:

<table>
<thead>
<tr>
<th>Test Number</th>
<th>Description</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>D751</td>
<td>Tensile Strength</td>
<td>Warp – 80 lbs</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fill – 90 lbs</td>
</tr>
<tr>
<td>D751</td>
<td>Seam Strength</td>
<td>85 lbs</td>
</tr>
<tr>
<td>D751</td>
<td>Tear Strength (Tongue)</td>
<td>Warp – 6 lbs</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fill – 7 lbs</td>
</tr>
<tr>
<td>D1117</td>
<td>Tear Strength (Trapezoid)</td>
<td>Warp – 18 lbs</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fill – 20 lbs</td>
</tr>
<tr>
<td>AATCC-16A</td>
<td>Colorfastness – 200 hrs</td>
<td>No change</td>
</tr>
<tr>
<td>D751</td>
<td>Adhesion of Coating</td>
<td>10 lbs</td>
</tr>
<tr>
<td>Wyzenbeek 100k rubs #8 duck</td>
<td>Abrasion Resistance</td>
<td>No significant wear</td>
</tr>
</tbody>
</table>
15.16 RUBBER FLOOR COVERING

15.16.1 General

Rubber floor covering shall contain a minimum of 38 percent (nominal, by weight of compound) Butadiene Styrene rubber, shall be non-staining, non-discoloring, and 100 percent non-oil extended. Only high quality, fine, hard clay shall be used as filler. No whitening (limestone) shall be used in the compound. The rubber shall be free from reground rubber, natural rubber, or coarse fillers.

At 68°F, the rubber flooring shall bend 180 degrees around a ¾-inch diameter mandrel without breaking, cracking, crazing, or showing any change in color. The rubber flooring material shall be fully homogeneous throughout and shall meet the requirements of ASTM F 1344.

15.16.2 Inspection Criteria

15.16.2.1 Thin-Skinned Blister

A thin-skinned blister is a blister which, when finger pushed, shall collapse upon itself. Any thin-skinned blisters which exceed the limits listed below shall be cause for rejection of the floor sheet.

- Maximum Size – 0.030-inch high, 0.80-square inch area with longest dimension of 2-inches.
- Maximum Population – three blisters in a 12-inch x 12-inch area with only one other blister within 3 feet of this area.

Repair Method – using a hypodermic needle, apply just enough Super Bond 420 or Bostik 1685 or equivalent, compress the blister and bring to a flush surface.

15.16.2.2 Thick-Skinned Blister

A thick-skinned blister is a blister which, when finger-pushed, shall collapse and then returns to its original condition.

- Maximum Size – 0.030-inch high, 0.80-square inch area with longest dimension of 2-inches.
- Maximum Population – three blisters in a 12-inch x 12-inch area, and only one other blister within 3 feet this area.

Repair Method – no repair authorized, not an acceptable condition.

15.16.2.3 Lump

A lump is a blister without a void, consisting of solid material.

- Maximum Size – 0.030-inch high, 0.80-square inch area with longest dimension of 2-inches.
• Maximum Population – three 12-inches x 12-inch area, and only one other lump within 3 feet of this area.

Repair Method – no repair required.

15.16.2.4 Hole

A hole is a defect which is 50 percent or more through the material. Any holes found in the floor sheet shall be cause for rejection of the sheet.

15.16.2.5 Thin Area

A thin area is a defect where the sheet is of reduced thickness locally.

• Maximum Size – 0.030-inch deep at the lowest point, 3 square inches with the longest dimension of 5-inches.

• Maximum Population – one thin area in a 40-inch x 40-inch area, and no other thin area within 3 feet of this area.

Repair Method – rub with #00 steel wool to blend this area into the normal thickness material and then buff to a normal surface finish.

15.16.2.6 Color Distribution

Color distribution is an appearance judgment and shall be subject to the approval of SEPTA. If the base coloring is not within 5 percent between production runs or the coloring is not consistent over the entire surface, the roll shall be rejected.

15.17 PAINTS AND COATINGS

15.17.1 General

The painted portion of the carbody, or any of its components, shall be painted as required by the Specification. Austenitic stainless steel portions of the carbody shall not be painted, unless otherwise approved by SEPTA for cosmetic reasons. Where stainless steel is painted, procedures shall be as recommended by the paint manufacturer for the application, and surfaces shall be properly prepared to ensure adhesion.

All painting on the carbody or any component shall be performed in accordance with the paint manufacturer’s recommendations. To the greatest extent possible, all exterior paint application for a given vehicle shall use the same paint batch to assure uniformity of appearance. The Contractor and its paint supplier shall submit a touch-up procedure and assure that a continuing supply of touch-up paints
in colors used on the locomotive, suitable for spot application by spray, roller, or brush, shall continue to be available in the United States.

15.17.2 Materials and Preparation

Before painting any locomotive surface that is exposed to view, all dents, gashes, nicks, roughness, or other surface imperfections or depressions shall be removed, in so far as possible, by straightening and shall then be properly prepared to receive a filler material. If the filler material is provided by a manufacturer other than the manufacturer of the paint system, a letter from the paint manufacturer shall be required stating that the filler is compatible with the paint system. These surfaces shall be properly cleaned and wash primed following straightening. Any remaining dents or other surface imperfections shall then be filled with approved filler and sanded smooth. The maximum allowable filler thickness shall be as recommended by the filler manufacturer for the environment and service to which it is to be exposed, but in no case shall it exceed 0.125-inch.

Preparation of the substrate surface and application of painting materials by roller, brush, or spray shall be in accordance with the paint manufacturer’s recommendations. Only primers recommended and approved by the paint manufacturer shall be used. All paint materials shall be used at the consistency recommended by the paint supplier. If thinners are necessary, they shall be approved by the paint manufacturer and shall be used only to the extent recommended. Painting shall be performed by experienced labor, using proper equipment under competent supervision following documented and approved procedures.

Painting materials for all surfaces shall provide a high quality finish resistant to corrosion, chipping, fading, and shall retain the gloss level. The coating shall be a two-part, high solids, low VOC, polyurethane paint system. All components of the paint system shall be provided by the same manufacturer. All paint and filler materials which are to be superimposed to form a finish system shall be mutually compatible and shall be warranted for use as a system by the manufacturer of the components.

Metal portions of the carbody not constructed of austenitic stainless steel shall, after fabricating, be prepared for painting by grit blasting and immediately painted with an approved epoxy primer, or washed with an alkaline solution, properly rinsed, phosphate coated, or painted with a coat of wash (etch) primer, and then coated with an approved epoxy primer. After erection of the framing structure and body sheets, all undercar metal, except stainless steel, shall receive a polyurethane finish as specified above. The exterior finish shall have a gloss level of 85 +/- 5 as measured with a 60 degree Glossometer. The supplier shall submit color samples and corresponding gloss and tri-stimulus values for approval.

Alternate paint systems, such as base coat-clear coat systems, or direct-to-metal paint systems shall be considered if the paint performance equals or exceeds that of a two-part polyurethane paint system.

15.17.3 Exterior Painting

All exterior surfaces that are to be painted shall be prepared as specified, and the paint shall be applied according to the paint manufacturer’s recommendations. The paint shall be uniformly applied over all surfaces to be covered and shall be free from runs, sags, or other application defects. Painting shall be
performed in a clean, dry atmosphere at an ambient temperature as recommended by the paint manufacturer.

The final painted surface shall be tested on the first locomotive to the following criteria:

1. **Hardness**
   All exterior paints shall be Imron or equivalent

2. **Adhesion**
   Adhesion shall be tested per ASTM D 4541 and achieve a minimum rating as provided by the paint manufacturer. To avoid a destructive test of a vehicle’s surface, which would require the tested surfaces to be repaired, the use of a test structure for this test may be proposed for consideration.

3. **Thickness**
   The minimum and maximum dry film thicknesses shall be provided by the paint manufacturer. Dry film thicknesses beyond the manufacturer’s recommendations shall not be accepted. Non-destructive testing shall be performed to verify final dry film thickness.

4. **Paint Cure**
   A solvent rub test shall be performed per ASTM D 5402. The test procedure requires no less than 50 double finger rubs with a cloth wetted in acetone or methyl isobutyl ketone to the painted surface. No paint color shall transfer to the cloth. After 72 hours, the painted surface must retain all original gloss and hardness characteristics.

### 15.17.4 Apparatus and Underfloor Equipment

All underfloor- and overhead-mounted apparatus (motors, control boxes, junction boxes, brake valves, and other equipment as specified) shall be primed and painted in accordance with the following requirements unless otherwise indicated. All other apparatus shall be painted in an approved color.

The exterior surfaces of undercar equipment enclosures and apparatus, other than propulsion control equipment, made from carbon steel shall be prepared, primed, and painted, as specified. The interior and exterior surface of all electrical equipment enclosures shall be coated with an approved insulating, thermosetting, resin-based, powder coating or polyurethane paint system. The interior of the boxes, including insides of covers, shall be white and the exteriors shall match the undercar paint scheme.

Parts of undercar equipment enclosures made from plastic or fiberglass shall be painted in accordance with the above requirements for metal portions, except that the paint system shall be compatible with the plastic used and an insulating coating need not be applied.

### 15.17.5 Painting Restrictions

Any equipment or parts of equipment which can be damaged or suffer impaired operation from painting shall not be painted and shall be corrosion resistant.

The following items shall not be painted:
• Copper tubing, piping, and fittings;
• Wearing surfaces;
• Couplers, including yoke and draft gear;
• Wire and cable;
• Power resistors;
• Heat transfer surfaces;
• Electrical insulators;
• Elastomeric parts;
• Grounding pads; and
• Conduit and fittings.

The following truck-related items shall not be painted, unless approved by the Engineer:

• Wheels;
• Axles;
• Elastomeric parts;
• Grease fittings;
• Linkages;
• Threaded adjustment parts;
• Electrical equipment; and
• Wearing Surfaces.

### 15.17.6 Interior Painting

All exposed interior surfaces, including molding and trim, shall be as specified. Interior surfaces requiring painting shall be coated with an approved painted finish. Parts which are to be painted shall be cleaned and prepared in accordance with the recommendations of the paint manufacturer.
The Contractor and its paint manufacturer shall provide a touch-up procedure and assure that a continued supply of touch-up paint in the proper colors suitable for spot application shall continue to be available in the United States.

15.17.7 Corrosion Protection

The design of the car shall avoid the trapping and retention of water and debris. All surfaces shall be completely free of rust, scale, grease and other foreign matter immediately preceding the application of the primer. All joints shall be properly sealed with an approved waterproofing compound that will be compatible with the coatings applied. All surfaces that are concealed after assembly shall be properly cleaned and coated with an approved preservative coating in a manner recommended by the coating manufacturer, especially inside surfaces of fabricated items. Where possible, dip coating of sections is preferred. Any arc welding performed on stainless steel shall be thoroughly cleaned and, if necessary, coated with an approved stainless steel coating material.

All aluminum surfaces, where required, shall be properly cleaned and shall be given a coating of an approved zinc chromate material. All joints between aluminum and other metals shall be suitably waterproofed and insulated with an approved compound which shall cover the entire area of each contact surface and conduct heat, if necessary. Aluminum heat transfer surfaces shall be anodized. If approved by the Engineer, heat transfer surfaces may be irridite to Military Specification MIL-C-5541E, Class 3, followed by priming and painting, provided that this treatment can demonstrate corrosion protection equivalent to anodizing.

15.17.8 Powder Coatings

Powder coating materials are to be epoxy based or approved equal as recommended by the powder coating manufacturer for the specific application. The coating shall have a finished thickness between 1.5 and 2.5 mils. The surface to be powder coated shall be prepared in accordance with the powder coating manufacturer’s published recommendations. Powder coated parts which are scratched during handling and installation shall be touched up using a matching color epoxy paint that is allowed to cure prior to installation. Epoxy based powder coatings of middle to high gloss level shall have a minimum impact strength of 120 inch-pounds when tested in accordance with ASTM D 2794.

15.17.9 Acoustic Insulation

Acoustic insulating materials shall be applied to properly cleaned underframe, sides, ends, roof and floor sheets, in accordance with the supplier’s recommendations. The materials shall be resistant to dilute acids, alcohols, grease, gasoline, aliphatic oils, and vermin. The material shall be unaffected by sunlight and ozone and shall not become brittle with age. It shall be Daubert Chemical Company’s V-Damp 3680 sound deadening compound, 3M Corporation’s 2552 Damping Foil, or approved equal.

15.17.10 Paint Process Documentation

The Contractor shall prepare detailed paint coating and application documentation containing manufacturer’s product data sheets, procedures for surface cleaning and preparation, priming, surfacing, and painting for the carbody and all equipment that is to be painted or powder coated, as well as touch-up and repair procedures. A detailed paint schedule showing the equipment painted, paint
type and manufacturers’ recommendations for thickness, and other pertinent parameters shall also be included. This document shall be submitted for approval prior to painting of any surfaces or components and shall be made part of the maintenance manuals.

15.17.11 Truck Painting

All truck components to be painted shall be given a full coat of primer prior to assembly. Following assembly, all exposed surfaces of each truck, including machined mounting surfaces not used, shall be cleaned with compressed air and solvent wiped to remove all dirt and grease. These surfaces shall then be sprayed with one coat of an approved black truck paint of a type which shall not conceal cracks that may develop in service, and air-dried.

15.17.12 Decals

Preparation and application of decals shall be in accordance with the decal supplier’s recommendations. Where appropriate, decals may be embedded in the paint system and shall be processed so as not to void any warranties from the paint or decal manufacturers. Edge seal shall be used on applications where the decal is not embedded in the paint to protect the decal and its adhesive from cleaning solutions and automatic washing brushes.

1. Logo –
   A logo design shall be applied to the locomotive exterior in an area to be selected by SEPTA. Logo design shall be furnished by SEPTA. SEPTA’s logo shall be made of exterior type reflective decorative vinyl film, 3M "Scotchlite" or approved equal

2. Locomotive Numbers –
   The locomotive number shall be applied to the outside of the car bodies in areas to be approved and in a sequence also to be selected by SEPTA. The Contractor shall submit side and elevation drawings to SEPTA on which SEPTA will indicate the lettering style and symbols desired

3. Reflectorization –
   Red high reflective tape with sealed and rolled edges shall be applied around the carbody sill

4. Contractor’s Name Plate –
   Two permanent builder's plates shall be applied to the exterior of each locomotive. Plate size, wording and location shall be approved by SEPTA. The ownership plate, if required, and Contractor’s name plate shall be stainless steel, with etched and painted lettering
15.18 FLAMMABILITY, SMOKE EMISSION, AND TOXICITY REQUIREMENTS

15.18.1 General
All combustible materials used in the construction of the locomotives shall satisfy the flammability, toxicity and smoke emissions requirements of this Section and 49 CFR 238.103 and NFPA 130. In case of conflict, the more restrictive requirement shall prevail.

The Contractor shall comply with all provisions of 49 CFR 238.103 (c), “Fire Safety Analysis for Procuring New Passenger Equipment”, and APTA RP-PS-005-00, “Fire Safety Analysis of Existing Passenger Rail Equipment”. The Contractor shall prepare and submit a Fire Safety Analysis of the design and materials of construction of the vehicle as part of the design phase of the Contract to be submitted to SEPTA for review and approval prior to construction.

Test reports from an independent laboratory indicating successful testing and demonstrating compliance with these requirements for all materials shall be submitted to SEPTA for review and approval. Testing shall be conducted after the Contractor’s NTP and on a production batch of material intended to be used on the vehicle. Each laboratory shall have tested a standard test sample no greater than 30 days prior to performing the tests, the results of which shall be submitted to SEPTA. The Contractor shall be responsible for complete conformance with the requirements for itself and its subcontractors and suppliers. SEPTA may, at its discretion, require that the current batch of production material provided for this Contract be retested for conformance with these requirements.

The Contractor shall submit a Fire Safety Analysis Report for SEPTA approval.

15.18.2 Combustible Content
The design of the vehicle shall minimize the total combustible material content of the vehicle. A matrix showing the total weight of all combustible materials, where used, flammability, smoke emissions, test identity, test facility, test requirements, test results, nature, and quantity of the products of combustion, caloric content, and peak heat release rate per ASTM E1354 shall be submitted by the Contractor during detailed design review for SEPTA’s approval. All materials with a surface area greater than 16 in² shall be tested at a flux radiance of 50KW/m². As a minimum, the following materials shall be tested: seating materials, wall coverings, window masks, fiberglass components, insulations, plymetal walls, floor covering, floor panels, non-metallic equipment boxes and covers, window glazing, lighting lenses and diffusers, window gaskets, door seals, HVAC in-air stream components, grills, door nosing, filters and, electrical wire and cable insulation.

15.18.3 Flammability and Smoke Emission
All materials used shall be tested to demonstrate compliance with the requirements set forth in 49 CFR 238.103 and NFPA 130. The Contractor shall submit test reports for all materials tested and a summary table to SEPTA for approval.
The Contractor shall test the cab floor assembly in accordance with ASTM E119 to demonstrate a 30-minute endurance rating. The test procedure, test facility, and test results shall be approved by SEPTA prior to the Contractor’s procurement of any flooring material necessary for vehicle production.

The test specimen shall be a full width vehicle section including side sills or that portion of the wall which extends below the floor. If approved, the exposed area may be reduced to meet a length limitation imposed by the size of the test furnace, but the length shall not be less than that of the actual cab. No fewer than two (2) typical penetrations, spaced at a distance from each other no greater than that which shall exist in actual construction, shall be included in the test specimen floor splice configurations, any penetrations through the floor including but not limited to ventilation ducts, conduits, etc, and any areas of the floor that are thinner than the standard floor section. The specimen shall include typical floor splice configurations. Test specimen shall be loaded to approved loading conditions. The concentrated loads shall be applied to simulate underfloor equipment. The Test specimen shall include at least three typical transverse supports. The test specimen shall represent the actual construction utilized in production. This includes the floor covering, floor boards, floor structure, thermal and acoustical insulation, and floor pans.

The Conditions of acceptance for this test shall be those required for unrestrained assembly.

15.18.4 Toxicity

Materials and products identified by state agencies, federal agencies, and the American Conference of Governmental Industrial Hygienists (ACGIH) as containing toxic properties or to emit toxic products of combustion in excess of the limits defined herein shall not be used. Materials and products generally recognized to have highly toxic products of combustion shall not be used.

All materials used in the locomotive construction, except for materials used in small parts such as knobs, rollers, fasteners, clips, grommets, and small electrical parts that would not contribute significantly to fire propagation or to smoke or toxic gas generation and are distributed throughout the locomotive, shall be tested for toxicity using Boeing Specification Support Standard BSS-7239. Alternative test protocols may be proposed for SEPTA’s consideration providing that the results are reported as noted below. Materials shall meet the following maximum toxic gas release limits (ppm) as determined per BSS-7239:

<table>
<thead>
<tr>
<th>Material</th>
<th>Limit (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon Monoxide (CO)</td>
<td>3,500 ppm</td>
</tr>
<tr>
<td>Hydrogen Fluoride (HF)</td>
<td>200 ppm</td>
</tr>
<tr>
<td>Nitrogen Dioxide (NO2)</td>
<td>100 ppm</td>
</tr>
<tr>
<td>Hydrogen Chloride (HCL)</td>
<td>500 ppm</td>
</tr>
<tr>
<td>Hydrogen Cyanide (HCN)</td>
<td>150 ppm</td>
</tr>
<tr>
<td>Sulfur Dioxide (SO2)</td>
<td>100 ppm</td>
</tr>
</tbody>
</table>

The tests shall be conducted in the flaming mode after 240 seconds using the NBS Smoke Density Chamber for sample combustion. The gas sampling may be conducted during the smoke density test. The test report shall indicate the maximum concentration (ppm) for each of the above gases at the specified sampling time and shall be submitted to SEPTA for review and approval.
15.18.5 Electrical Fire Safety

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

15.19 PIPING AND TUBING

15.20 General

All piping valves, fittings, installation methods, and testing shall be in accordance with the EN and Code for Pressure Piping, ANSI B31.1. All joints shall be easily accessible. Piping and fittings that SEPTA would expect to change shall be to ANSI B31.1. Other piping and fittings may be to EN standards and will be approved by SEPTA on a case by case basis.

Following installation, all piping systems shall be cleaned to remove dirt, metal chips, oily contamination, and moisture. After cleaning, all piping systems shall be pressure tested in accordance with the latest edition of the Code for Pressure Piping, ANSI B31.1. All leaks shall be repaired and the system re-cleaned and retested until leak-free.

Pipes shall be supported throughout their length and at all connections to prevent vibration or noise and to limit stresses in the pipe to less than 50 percent of the pipe’s fatigue endurance limit. Pipes and their connections shall not interfere with the removal of other components. Pipe routing and support shall be planned and accomplished in an efficient, organized manner to keep the total length and number of fittings and bends to an absolute minimum. All changes in direction shall be accomplished by bending the pipe to a radius of not less than that specified by AAR Specification Number 2518, Standard S-400. Direction-change fittings shall not be permitted in the trainline brake pipe or in the brake cylinder pipe. Support and clearances provided between adjacent pipes and between pipes and surrounding structure, equipment, or other appurtenances shall be sufficient to prevent chafing or contact due to any combination of locomotive loading and deflection, locomotive dynamics, and thermally-induced movement. The minimum clearance shall be 1/8-inch.

At all locations where pipe or tubing passes through holes in the floor, bulkheads, structure, or any fixed member, it shall be rigidly clamped to protect against possible damage or noise due to bearing, abrasion, or locomotive dynamics-induced rattling. Clamps shall not be welded, brazed or otherwise permanently fastened to any pipe or tubing. Pipe and tubing interfaces with clamps shall be insulated with an elastomeric or woven non-asbestos mineral fabric tape material to protect and sound-insulate the pipe or tubing.

Wherever carbody piping interfaces with vibration-isolated rotating equipment such as the air compressor and air conditioning compressor-condenser unit, approved flexible vibration eliminators shall be used. The pipe connection at either end of the flexible elements shall be rigidly clamped no farther than 2-inches from the flexible elements. All pipe clamps shall be inherently rigid and shall be firmly attached to locomotive structure. Cantilevered clamps or clamp supports that are weaker than service-proven designs shall not be accepted. All clamps shall be of a suitable material for the application.
Prior to constructing the locomotives, the Contractor, in cooperation with the manufacturers and suppliers, shall make a thorough analysis of the design of the pneumatic systems proposed for the locomotives to assure that every reasonable precaution has been taken in design and installation to prevent the locomotives from disablement in service as the result of adverse winter conditions. Before being granted permission to commence construction, the Contractor shall submit to SEPTA the details of its analysis and of any special preventative measures it proposes to incorporate in the design. The design layout, installation, and hanging methods, etc., shall be jointly inspected and reviewed with and approved by SEPTA.

### 15.20.1 Air Piping, Tubing, and Fittings

The main reservoir pipe and brake pipe shall conform to ASTM A53 or ASTM A106, Schedule 80 seamless pipe. Where ASTM A53 or ASTM A106 piping is provided, its application shall also comply in all respects to AAR Specification No. 2518, Standard 400, latest revision.

Type “K” annealed copper tube per ASTM B88, latest revision, or approved equal, may also be used, provided it is installed no lower than 2 inches below the floor sheet or structural member and is protected by means of equipment or approved steel guards from any potential impact damage from rail debris, especially in the truck and outboard of the bolster areas. Approved copper tube shall also comply with any relevant requirements of AAR Specification No. 2518. Where suitable protection in damage-prone areas is not possible or practical, approved steel or stainless steel piping sections shall be provided. All joints for copper tubing shall utilize fittings of wrought copper or non-porous cast brass in accordance with ANSI B16.22 and B16.18.

All air hoses shall conform to the requirements of AAR Specification M-618 with AAR approved reusable fittings meeting AAR Specification M-927.

All air piping must comply in all respects with the air brake supplier’s design and installation requirements. The diameter of the main reservoir pipe and brake pipes shall meet the brake supplier’s requirements; however, in no case shall these pipes be less than 0.875 inch outside diameter. All air pipes shall be sized in accordance with the function intended and may be either ASTM A53 or ASTM A106 schedule 80 pipe or seamless copper tubing as described previously.

Within one hundred-eighty (180) days of Contract Award and prior to manufacture of production locomotives, the Contractor shall provide SEPTA with a report containing written approval from the air brake supplier of the Contractor’s air brake piping fabrication, installation, and design concept. The following information shall be contained in the report:

- All critical line sizes and materials including the main reservoir pipe, the brake pipe, and the brake cylinder piping.

- The installation details of all critical lines including routing, total length and volume, elevation and slopes, and major joint and direction change locations. A list of all proposed bend radii shall also be provided.

- Pipe processing details including welding, brazing, cleaning, and fabrication methods.
• Locations of all major air brake valves and controls, relay, and emergency venting devices, and the proposed location and volume of all reservoirs.

• An air consumption analysis justifying the proposed air storage system design.

All air piping shall be installed in a manner to provide drainage away from devices, or branch pipes leading to devices, when the function of those devices could be impaired by the accumulation of water or ice.

All cut-out cocks shall be of the vented type, except where function prohibits. All cut-out cock handles and their arrangements shall be as described in Section 11.5.4.11.

Air piping on the trucks shall be 0.50 inch ASTM A53 or A106, Schedule 80, or approved equal. Low spots (traps) are strictly prohibited on the trucks. Truck piping shall not be run on the bottom of truck side frames, transom, or bolster, unless approved by SEPTA.

Where steel piping is used, all connections and joints where disassembly for service may be required shall utilize swivel type butt-welded flange fittings with an “O” ring type seal. The use of threaded fittings is expressly prohibited. Approval may be granted for the use of threaded fittings in extreme cases where adequate proof is provided that flanged fittings cannot be used.

15.20.2 Air Conditioning System Piping, Tubing, and Fittings

Air conditioning refrigerant lines shall be of seamless copper tubing, ASTM B88 type “K” or type “L” or ASTM B280, with wrought copper sweat type fittings. Refrigerant lines below the upper surface of the floor or subject to damage during operation shall be ASTM B88, type “K” only. Condensate drain lines shall be seamless copper tubing, type “K” or seamless stainless steel tubing.

Joints shall be kept to a minimum and all inaccessible runs of tubing shall be without joints. Finned tubing in evaporators and condensers shall be copper. Instead of elbows, tubing may be bent utilizing a bending tool designed specifically for bending of the tubing to be used.

Suction lines shall be designed and installed without traps. The suction line shall be sized for 3 psi (gauge) maximum system pressure drop and the liquid line shall be sized adequately to prevent flashing due to pressure drop.

Lines subject to condensation shall be insulated with an approved insulation, applied with approved contact cement. The liquid line shall be insulated in all areas where required to provide additional mechanical or thermal protection. Insulation at all joints and fittings shall be mitered and sealed with an approved material. The insulation, adhesive, and sealant shall meet the Specification requirements for thermal, smoke emission, and flammability performance.

All piping and pipe subassemblies shall be deburred, cleaned, dried, and capped with tight fitting plastic caps, or approved equal on all openings after fabrication. Caps shall remain in place until immediately prior to incorporation into the final assembly.
Vibration eliminators shall be used in piping connections to the compressor unless deemed unnecessary by SEPTA. Tubing installations shall be designed so that ease of maintenance can be achieved, as approved by SEPTA.

Tubing installations shall be designed to allow any single length of tubing to be replaced without dismantling or removing surrounding equipment, piping, wiring, or other appurtenances. This requirement does not apply to piping within a self-contained modular HVAC unit.

### 15.20.3 Brazing and Soldering of Piping, Tubing, and Fittings

All brazing and soldering shall comply with the applicable parts of section 15.4 and the following requirements. All refrigerant piping and air system copper tubing shall be joined using silver solder conforming to Federal Specification QQ-B-654A, BAg-5 or BCuP-5. Refrigeration piping and tubing shall be internally swept with a continuous flow of a non-oxidizing gas such as dry nitrogen during brazing. Condensate drain tubing shall be joined using 95-5 solder or silver solder as above. Solder joints shall be wiped and have flux cleaned from tubing and fittings after soldering. After fabrication, the refrigeration and air systems shall each be cleared of all dirt and foreign matter, flushed with a degreasing agent and dried, all according to a procedure prepared for each by the Contractor and submitted to SEPTA for approval.

### 15.20.4 Water Piping and Fittings

Water piping shall be seamless copper tubing, type K, with sweat type fittings of wrought copper or cast brass. Piping shall be sloped to allow drainage. Low points in piping shall be equipped with automatic drain valves, Ogontz PP39FR or approved equal, which shall discharge all the water in the locomotive to the tracks whenever the water temperature in the locomotive falls below 38°F. Manual drain valves shall also be provided. Anti-freeze protection (heat trace tape) shall be provided for the water fill housings, associated underfloor water piping, water system drain pipes, water tanks, and the Ogontz valves.

### 15.20.5 Sewage Piping and Fittings

All waste piping lines shall be minimum 2 inch seamless stainless steel or cast iron tubing with welded type fittings of stainless steel. Sharp angles are to be avoided and "sweep" fittings shall be no more than 45 degrees.

Cleanouts must be provided in areas where blockage might occur. Sewage piping should at all points slope with downward flow. Anti-freeze protection (heat trace tape) shall be provided for the sewage piping, tank, and all valves.

### 15.20.6 Pressure Vessels

All pressure vessels shall conform to the latest revision of Section VIII of the ASME Boiler and Pressure Vessel Code for Unfired Pressure Vessels. Test reports shall be furnished for each pressure vessel, and each pressure vessel shall be stamped to document the test.
15.21 AIR FILTERS

15.21.1 HVAC and Equipment Ventilation Filter
Filters shall be selected in accordance with the manufacturer's recommendations for the specific equipment involved. All filters shall have an integral frame. Filters shall be the throw-away type, except reusable filters may be approved for specific applications where throw-away filters are not available. Filters shall be designed to meet the performance requirements of each installation, and shall be approved. All filters shall be freely accessible for maintenance.

15.21.2 High Pressure Air Filters
Air filter assemblies with replaceable filter elements shall be provided in the air line that connects each subsystem to the air supply system. The air filter filtering capability, flow rate capability, and overall size shall be appropriate for the application so that the filter replacement interval is greater than one year. It shall be possible to gain access to the filter element for replacement without requiring any pipe fittings to be disconnected or loosened. Filters shall be provided for each of the following systems and any others operated from the air supply system:

- Each air brake control assembly,
- Input and output of each height control valve,
- Door operators (if pneumatic),
- Horn.

15.21.3 Low Pressure Air Filters
Replaceable media type filters shall use resin-bound, spun-glass fiber materials having an uncompressed thickness not less than 3-1/2 inches. It shall be non-absorptive of fluids and gases, shall be processed in such a manner that material density increases progressively from air inlet to air exit side, and shall be coated with not less than 24 grams per square foot of a dust-retaining, viscous adhesive film. This film shall be stable at temperatures up to 150°F. The filter medium shall be cut not less than ½ inch oversize to ensure adequate sealing between the edge of pad and its integral frame.

15.22 WIRE AND CABLE

15.22.1 General Requirements
The Contractor’s design and construction shall ensure that the minimum number of wire types and sizes shall be used in the vehicle.
Selection of wire sizes and insulations shall be based on the current carrying capacity, voltage drop, mechanical strength, temperature and flexibility requirements in accordance with applicable APTA, AAR, ICEA, ASTM, NEC, and MIL Specifications. However, in no case shall the properties of the wire and cable be less than those properties delineated in this specification. Extra-fine wire stranding shall be utilized on applications subject to repetitive motion.

All applications of shielded cable shall be subject to the approval of SEPTA.

The Contractor and each manufacturer of equipment through the Contractor shall submit to SEPTA for approval samples at least 12 inches long, specifications, and 3 copies of certified qualification test documentation of each size and type of wire and cable specified before utilizing said wire and cable.

15.22.2 Conductors

Conductors for wire AWG No. 12 and smaller shall be soft, annealed nickel plated copper constructed in accordance with MIL-W-22759/6B. Conductors of all sizes insulated with irradiated, cross-linked polyolefin wire shall be soft, annealed tinned copper, in accordance with ASTM B33. Minimum stranding shall conform to AAR Standard S501, S502 (No. 589), or ASTM B-172 Class K, or ICEA S-66-524/NEMA WC7, Table L-7, Class K for AWG No. 10 or larger, as appropriate for the application.

Stranding and conductor construction for wire sizes AWG No. 12 to AWG No. 16 shall be in accordance with AAR Recommended Practice RP-585, ASTM B-174, Class K, or ICEA S-66-524/NEMA WC7, Table L-8, Class M, as appropriate for the application.

Stranding and conductor construction for wire sizes AWG No. 18 and smaller shall be in accordance with ASTM B-174 Class L or ICEA S-19-81/NEMA WC3, Table L-8, Class M, or shall be nineteen (19) strand construction as appropriate for the wire size.

The use of solid wire shall not be permitted except for approved wire wrap applications.

Wiring shall be sized for the intended load, voltage drop, installation method, and applicable codes. Calculations of wire sizes shall be in accordance with APTA-RP-E-009-98, “Recommended Practice for Wire used on Passenger Equipment.” When the free air rating is used, the Contractor shall furnish data to show that the cables shall not exceed their rated temperature at the rated current. Wire ampacities shall be de-rated to meet the temperature requirements of all devices to which the wire connects. When short time ratings, short time overload temperatures, and thermal time constants are used to determine cable size, the parameters used shall be submitted for approval.

In no case shall wire smaller than the following sizes be used:

- Wire which is pulled through conduits or wire ways - AWG No. 14.
- Wire on electronic units, cards, and card racks - AWG No. 28.
- Wire within control compartments - AWG No. 18.
- A multi-conductor cable where current is not a factor in wire size selection - AWG No. 18.
• All other wire, including that which is not pulled through wire ways and conduits - AWG No. 16.

SEPTA may approve smaller wire sizes for selected applications upon submission of appropriate applicable data for justification.

15.22.3 Insulation

15.22.3.1 General Wiring Insulation

Teflon, mineral filled, abrasion resistant insulation may be used on wire sizes AWG No. 12 to AWG No. 28. Otherwise, for all general locomotive body wiring, the insulation shall be a flame retardant, flexible, irradiated cross-linked polyolefin material having a continuous temperature rating of 230º F. The insulation shall be rated at 2,000 VAC and VDC, in the case of wires carrying a nominal voltage greater than 150 VAC or VDC, and rated at 600 VAC and VDC, in the case of wires carrying a nominal voltage of 150 VAC or VDC or less. For wire sizes AWG No. 6 and larger, the insulation material shall be formulated for extra flexibility.

Insulation shall meet the following flammability requirements:

• Cross-linked polyolefin shall be tested in accordance with test method ICEA S-66-524/NEMA WC7, Paragraph 6.12.5. After five (5) applications of fifteen (15) seconds each, with a three second rest period between applications, flame shall extinguish in ten (10) seconds or less.

• Other insulation materials shall be tested in accordance with IEEE-383.

15.22.3.2 Cross-Linked Polyolefin Wire Insulation

The irradiated cross-linked polyolefin wire insulation shall be constructed and tested in accordance with the following requirements:

1. Flexibility Tests for Cables
   Flexibility tests for cable sizes up to AWG No. 2/0 shall be performed in accordance with AAR Recommended Practice RP-585, paragraph 5.9.7.1, for the appropriate wire size.

   Flexibility tests for cable sizes AWG No. 2/0 and larger shall be performed in accordance with AAR Recommended Practice RP-585, paragraph 5.9.7.

2. Single Conductor Thermal Overload Test
   A continuous current of 115 Amperes shall be applied to an 18 foot length of AWG No. 10 test wire in 77ºF still air. A 3000C VDC potential shall be maintained between the test wire and an AWG No. 18 bare copper wire wrapped snugly around the outer insulation surface of the test wire. Failure shall occur when a short circuit is established between the bare copper wire and the test wire. Minimum time to failure shall be 3 minutes.
3. Bundle Overload

A bundle overload test using a 7 wire bundle shall be performed in accordance with AAR Standard RP585, paragraph 5.9.1.

4. Temperature Cycling Tests

This test shall be performed on an 8 foot length of AWG No. 10 wire with 2 kV insulation. Thermocouples shall be attached to the outer jacket surface, and on the conductor, under a small incision in the insulation approximately 12 inches from one end of the sample. Both ends of the sample shall be securely clamped using hose clamps.

Prior to temperature cycling, the sample shall be conditioned for 2 hours at a temperature of 302°F.

The sample shall then be temperature cycled between ambient of 257°F and -22°F by transferring the sample between an air-circulating oven, set at 257°F and an air-circulating cold box set at -22°F. The time during which the sample stays in each chamber shall be sufficient to allow both thermocouples on the sample to read the same temperature as the environment.

One cycle shall be defined as an approved dwell time at both 257°F and -22°F. The sample shall be subjected to a total of 250 cycles, with a visual observation at the end of each cycle for cracks and other damage. After 250 cycles, the sample shall be immersed in water for 6 hours with both ends out of the water, and then subjected to a dielectric test of 5 kVAC for 5 minutes and also examined by microscope to verify that no cracks exist.

Flame-retardant, flexible, irradiated, cross-linked polyolefin insulation rated at 257°F may be used, provided that it meets the requirements of all the above tests and standards, modified to reflect the temperature rating related characteristics. The revised values, and the use of such wire, must be approved by SEPTA. Cross-linked polyolefin insulation shall not be permitted for use on wires connected to heater elements or any other high-temperature device.

15.22.3.3 Other Wire Insulation

All insulation other than irradiated, cross-linked polyolefin shall meet the following test requirements, based on MIL-W-22759, and using the following parameters:

1. Dielectric
   Test per MIL-W-22759/10B (for 1,000 V wire with tests at 9.5 kV impulses) or MIL-W-22759/6B (for 600 V wires with tests at 8 kV impulses).

2. Insulation Resistance
   Test per ASTM D-470. Minimum accepted value shall be 1,000 megohms per 1,000 feet, using a 1,000 VDC megohmmeter.

3. Spark test
One hundred percent of all single conductor cables and all single conductor cables being used in a multi-conductor cable shall be inspected by Impulse Dielectric Test or by chain electrode Spark Test. Spark Test Apparatus and Procedure shall be in accordance with MIL-W-22759. Spark Test voltages shall be equivalent to impulse test voltages by corresponding RMS value at 3 kHz.

<table>
<thead>
<tr>
<th>Impulse Test Voltage kV Peak</th>
<th>3 kHz Test Voltage kV RMS</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>5.7</td>
</tr>
<tr>
<td>9.5</td>
<td>6.7</td>
</tr>
<tr>
<td>10</td>
<td>7.1</td>
</tr>
</tbody>
</table>

4. Air aging
   Test per ASTM D-638. Age sample for seven (7) days at 302°F in an air oven. Minimum tensile strength and elongation shall not be less than 85 percent of the unaged values. Also test per IEEE STD 383-1974 and ASTM D-573 for extended life.

5. Cold Bend
   Test per NEMA WC3, except test temperature shall be -58°F.

6. Weight Loss
   Weight loss of the insulation material shall not exceed one percent when subjected to an oven temperature of 266°F for 500 hours.

7. Chemical Resistance
   An appropriate length sample shall be measured for insulation diameter and total weight to record initial values. The wire shall be immersed to within 3 inches of each end in the test fluid for 24 hours at 149°F. During the immersion stage, the minimum bend radius of the wire shall be ten (10) times the diameter of the wire being tested. Upon removal from the test fluid, the specimen shall be cooled to room temperature for 1 hour and the diameter gauged and reweighed for comparison with the original values. The maximum diameter and weight increase shall not exceed 30 percent. Typical fluids for this test include:

   - Humble No. 2214 Railroad Diesel Lubricating Oil and lubricants (100 percent solution)*
     Humble Diesel 260 or Railroad T fuel oil (100 percent solution);

   - Mineral oil (100 percent solution);

   - Hydrochloric acid, nitric acid, sodium hydroxide, sulfuric acid (0.1 percent solution);

   - Potassium hydroxide (0.1 percent solution);

   - Petroleum distillates and other graffiti removers and cleaning compounds;

   - Kerosene solvents (100 percent solution);
• Trisodium phosphate solution (50 percent solution);

• Skydrol 500 B hydraulic fluid (100 percent solution); and

Water.

8. Temperature Cycling Testing
The test shall be performed on an 8 foot length sample of AWG No. 12 wire.

Thermocouples shall be attached to the outer jacket surface and on the conductor under a small incision in the insulation about 12 inches from one end of the sample. Both ends of the sample shall be securely clamped using hose clamps.

The sample shall be conditioned for 2 hours at a temperature of 302°F. The sample shall then be temperature cycled between ambient of 257°F and -22°F by transferring the sample between an air-circulating oven, set at 257°F and an air-circulating cold box set at -22°F. The time during which the sample stays in each chamber shall be sufficient to allow both thermocouples on the sample to read the same temperature as the environment.

One cycle shall be defined as an approved dwell time at both 257°F and -22°F. The sample shall be subjected to a total of 250 cycles, with visual observation at the end of each cycle for cracks and other damage. After 250 cycles, the sample shall be immersed in water for 6 hours with both ends out of the water, and then subjected to a dielectric test of five (5) kVAC for 5 minutes and also examined by microscope to verify that no cracks exist.

9. Single Conductor Thermal Overload Test
A continuous current of 115 amperes shall be applied to an 18 inch length of AWG No. 12 test wire in 77°F still air. A 1,000-VDC potential shall be maintained between the test wire and an AWG No. 18 bare copper wire wrapped snugly around the outer insulating surface of the test wire. Failure shall occur when a short circuit is established between the copper wire and the test wire. Minimum time to failure shall be 3 minutes.

10. Seven-Wire Bundle Thermal Overload Test
A 7 wire cable bundle shall be formed by twisting 6 insulated AWG No. 12 conductors around a center insulated AWG No. 12 conductor.

A 120 Ampere current shall be passed through the center conductor for 7 minutes. After the test period, the cable bundle shall be examined for visible damage to the outer 6 conductors. Failure shall occur if any of the outer conductors split, rupture, or melt and adhere to the center conductor insulation.

11. Qualification and Production Tests
The tests required for this Specification concerning Qualification and Production shall be in accordance with tests in MIL-W-22759 for all lots produced.

All test reports covering Production and Qualification tests shall be submitted to SEPTA for approval with samples prior to any shipment of materials.
15.22.3.4 Wire Insulation for High Temperature Applications

High temperature insulation shall be used where connected to heat-generating apparatus, where the ambient temperature can exceed 257°F, or where Teflon is specified as a requirement. The insulation shall be rated at 1,000 VAC and VDC in the case of wires carrying a nominal voltage greater than 150 VAC or VDC, and rated at 600 VAC and VDC in the case of wires carrying a nominal voltage equal to or less than 150 VAC or VDC. The insulation shall have a continuous temperature rating of 257°C or above and be in accordance with the following requirements:

- For wire sizes AWG No. 16 and larger, abrasion resistant Teflon (Polytetrafluorethylene - PTFE) meeting MIL-W-22759/6B or 10B, as appropriate for the voltage level used, or silicone rubber meeting AAR Standard RP-587C.

- For wire sizes AWG No. 18 and smaller, abrasion resistant Teflon (PTFE) meeting MIL-W-22759/6B or 10B, as appropriate. When used for interconnecting pieces of apparatus, this type wire shall be in bundles with a protective covering of high temperature rated, low smoke generating insulation.

The Contractor may propose other insulated wire specifications for approval in a specific high temperature application, specifying the design ambient temperature, routing, RMS ampere value, worst-case ampere value, worst-case temperature rise, stranding, and insulation material specification.

No high temperature insulated wire shall be used in conduit or raceways without specific approval. The Contractor shall submit all applications of high temperature wire insulation for approval.

15.22.3.5 Wire Insulation within Equipment

Insulation on wiring within replaceable modular units, electronic apparatus such as cards and card racks, and other equipment, as approved, shall be Tefzel (Ethlenetetrafluoroethylene - ETFE) per ASTM D3159 and insulation construction per Military Specification MIL-W-22759/16 (AS), irradiated cross-linked polyolefin per Section 15.22.3.2, or Teflon (Polytetrafluorethylene - PTFE) type EE per Military Specification MIL-W-16878/5.

15.22.3.6 Wire Insulation at Crowded Locations

Wire for connections to the control console, or in any other locations where there are equally crowded concentrations of low voltage control wiring, may be insulated with Tefzel (ETFE) per ASTM D3159 and insulation construction per Military Specification MIL-W-22759/16 (AS), except the wall thickness shall be 0.025 inches. When used for this application, these type wires shall be bundled with a protective covering of irradiated cross-linked modified polyolefin or similar, approved, high temperature rated, low smoke generating insulation.
15.22.4 Multi-Conductor Cables

15.22.4.1 General
Multi-conductor cables, where approved, shall be constructed using wiring as described in Sections 15.22.5. For high temperature applications, the cable shall conform to MIL-C-27072, with Type V connectors, Style 4 sheaths, Class D jackets, if needed, and shields, if needed. All conductors in multi-conductor cables shall be color coded or otherwise permanently identified as approved. Materials used in the construction of multi-conductor cables shall meet the requirements below. In applications where current is not a factor in wire size selection, such as LED indicator lights or status displays, AWG No. 16 may be used between repeater devices and displays. For multi-conductor cables carrying low-voltage, high-speed, serial data, exceptions to the wiring requirements may be submitted for approval, based upon availability of wire to meet the application requirements.

15.22.4.2 Fillers
Where required to obtain a circular cross-section, fillers shall be made of non-hygroscopic materials compatible with the wire insulation and jacket, and shall be of the same or of a higher temperature rating than the wire insulation.

15.22.4.3 Tape
A binder tape shall be employed over the assembly of conductors in multi-conductor cables if needed to assist in cable manufacture, or as required to permit the cable to function as intended in its application. The binder tape material shall be non-hygroscopic and shall be of the same (or better) temperature class as the wire insulation, and shall be of a compatible material.

15.22.4.4 Shield
The shield, if required, shall consist of either tin plated copper braid (concentrically served) or aluminum/polyester tape with a drain wire, as is appropriate for the application. Tape shields shall be permitted for fixed installations only. The shields shall have the following minimum properties:

- Copper shield shall be made of either tinned, coated copper strands which conform to ASTM B33, or silver-coated copper strands which conform to ASTM B298, as is appropriate for the wire insulation. Shield coverage shall not be less than 85 percent. Shield strand size and application shall be as recommended by the cable manufacturer for the particular application, but shall not be smaller than AWG No. 38.

- Aluminum/polyester tape shields shall consist of a helical wrap of aluminum/polyester tape with a nominal thickness of 0.0004 inch aluminum on a backing of 0.001 inch polyester. The tape shall have a minimum overlap of 10 percent of the tape width to ensure complete coverage. In contact with the aluminum side of the shielding tape shall be a AWG No. 22 7/30 tinned copper drain wire conforming to ASTM B33 and B174.
15.22.4.5 Jackets

The overall jacket of multiconductor cables shall be of flame retardant, irradiated, cross-linked, modified polyolefin; Tefzel (ETFE); or Teflon (PTFE) to be fully compatible with the wire insulation and application as approved. The coupler cable shall have a jacket of low temperature arctic grade neoprene per MIL-C-13777, with a wall thickness suitable for 600 VAC. The jacket shall be extruded and vulcanized over the cabled conductors, and shall be centered, with a smooth appearance without objectionable roughness or irregularities, consistent with good industry practice. The nominal jacket thickness for polyolefin, Teflon, Tefzel and Neoprene shall be that shown below, with the minimum wall not less than 80 percent nominal value.

<table>
<thead>
<tr>
<th>Cable Diameter Under Jacket</th>
<th>Modified Polyolefin</th>
<th>Teflon or Tefzel</th>
<th>Neoprene</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.000-0.250</td>
<td>0.045</td>
<td>0.010</td>
<td>0.072</td>
</tr>
<tr>
<td>0.251-0.500</td>
<td>0.045</td>
<td>0.015</td>
<td>0.087</td>
</tr>
<tr>
<td>0.501-0.750</td>
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<tr>
<td>0.751-1.000</td>
<td>0.080</td>
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<tr>
<td>1.000-1.500</td>
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<td>1.501-2.000</td>
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</tr>
<tr>
<td>2.001-2.500</td>
<td>0.13</td>
<td>-</td>
<td>0.152</td>
</tr>
<tr>
<td>2.501-3.000</td>
<td>0.14</td>
<td>-</td>
<td>0.195</td>
</tr>
</tbody>
</table>

15.22.5 Wire Wrap

Wire wrap connections may be used in selected electronic applications, where approved. Where used, the following standards, as a minimum, shall be followed:

- Only soft or annealed oxygen-free solid copper conductor shall be used.
- Wire size shall be AWG No. 28.
- A silver conductor coating, with a minimum coating thickness of 40 micro-inches, shall be applied to the wire.
- Wire shall have "MIL-ENE" insulation, or approved equal manufactured to MIL-W-81822/1A. The insulation shall have a minimum 300 VAC/VDC voltage rating and shall allow a 275°F maximum conductor temperature.

Wrapping shall be “modified” wrap, nominal 7-1/2 turns, including 1-1/2 turns for strain-relief.
15.22.6 Insulation Smoke Test

15.22.6.1 Scope

This test method describes the equipment and the procedure for preparing insulated wire samples from which the specific optical density (Ds) of smoke generated can be determined in the Aminco-NBS Smoke Chamber. This method is used for wire sizes up to and including AWG No. 12. For wire sizes above AWG No. 12, the standard procedure outlined in ASTM E662 shall be used. Equipment calibration, standardization, and operation are to be in accordance with ASTM E662, Standard Test Method for Specific Optical Density of Smoke Generated by Solid Materials. The performance criteria shall be Ds (4.0) \( \leq 200 \) (flaming) and Ds \( \leq 75 \) (non-flaming).

15.22.6.2 Apparatus

- Aminco - NBS Smoke Chamber and Recorder.
- Aminco 6 tube, 90 degree burner assembly for flaming mode testing. Burners are all directed in one plane at the sample.
- Notchless wire frame (Aminco AWG No. 20 wire frame with notches machined off).
- Aminco troughless wire specimen holder assembly.
- Air oven.
- Humidification chamber.
- Heavy duty aluminum foil 0.001 ±0.0005 inch.
- Razor blade.
- Tape measure.

15.22.6.3 Procedure

Determine the length of insulated wire required for testing. The individual sample length shall be calculated to produce a sample area of 35 square inches.
• Calculate the sample length as follows:

\[
\frac{35}{1} = 3.1416 \times d
\]

where:

- \( l \) = sample length
- \( d \) = diameter of insulated wire (inches)

• Cut and identify a minimum of three samples of the required length.

• Condition samples prior to testing by pre-drying in an air oven for 24 hours at 140°F ±5°F followed by humidification at 73°F ±5°F, and a relative humidity of 50 percent ±5 percent, for a minimum of 24 hours.

• After conditioning, wind a sample uniformly around the wire frame so that the frame opening is uniformly covered.

• Cover the wire-wrapped frame with aluminum foil across the back, along the edges, and over the front surface's periphery with a single sheet of aluminum foil, with the dull side in contact with the wire.

• Place the foil-wrapped wire in a trough less sample holder such that the wire is vertically oriented. Insert millboard backing, spring, and retaining clip.

• Carefully trim the aluminum foil from the front opening of the sample holder.

• Adjust wire turns, if necessary, to assure that the sample holder opening is uniformly covered.

• Perform smoke testing in accordance with ASTM E662, noting any unusual behavior that occurs during the test; for example, self ignition of the sample in the non-flaming test mode or any extinguishment of a burner triplet during the test.

Report the sample orientation, test conditions, results, and observations made during the test.

15.23 WIRING, TERMINALS, AND CONNECTIONS

15.23.1 General

All locomotive wiring shall be in conformance with the AAR Manual of Standards, Section F 5-538, "Wiring Practice and Rolling Stock Standard", and APTA RP-E-002-98, “Recommended Practice for Wiring of Passenger Equipment,” except where otherwise specified, and except that all wire shall be as
required in this Specification. Circuit protection shall be in conformance with Chapter 2 of NFPA 70, Article 240.

All equipment enclosures and junction boxes, except primary power circuits, shall be fitted with terminal boards or connectors. Primary power circuits shall be fitted with compression terminals and knuckle joint connectors as described herein.

All wire passages into equipment enclosures, junction boxes and/or equipment boxes shall be protected and support to prevent any damage from chaffing and rubbing on surfaces.

The Contractor shall submit the proposed design and product line for all connections for approval. Terminal boards with M4 or Number 6 or smaller screws and quick-disconnect terminals, other than those stated herein, shall only be permitted with approval.

15.23.2 Wire Handling

All wiring shall be performed by qualified, experienced wiring personnel using appropriate tools for stripping insulation, cutting, tinning, soldering, harness making, attaching terminals, and other wire fabrication tasks. All wiring tools and equipment shall be used as recommended by the tool and equipment manufacturer.

Wire shall be protected from damage during all phases of equipment manufacture. Wire shall not be walked on, dragged across sharp or abrasive objects, kinked or twisted, or otherwise mishandled. The ends of wire shall not be permitted to lay on wet floors or other damp areas where moisture may be absorbed into the conductors.

When removing insulation, wire strands shall not be nicked or broken in excess of the requirements of FAA Specification No. AC 43.13-1A, Section 449, "Stripping Insulation".

Additionally, the following criteria apply:

<table>
<thead>
<tr>
<th>Wire Size</th>
<th>Maximum Number of Nicked Strands*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wires smaller than No. 10</td>
<td>None</td>
</tr>
<tr>
<td>No. 10 through 1/0</td>
<td>7.4 percent</td>
</tr>
<tr>
<td>Above 1/0 through 1600/24</td>
<td>4.4 percent</td>
</tr>
<tr>
<td>Above 1600/24</td>
<td>graduated scale</td>
</tr>
</tbody>
</table>

Definitions:

- A cutoff strand shall count as two nicked strands.
- A nick is defined as 25 percent or more of the strand area damaged, or cut more than 33 percent of its diameter.

Longitudinal scratches in a copper strand are not considered cause for rejection.
15.23.2.1  Wiring Layout and Installation

Wire Harness
The layout of wiring, for both locomotive and equipment, shall be designed in advance of its installation and in cooperation with the suppliers of the related equipment. Wiring shall be pre-fabricated into standard harnesses, wrapped or tied with spiral wrap or tie wraps. Harnesses shall be installed with identical arrangement and location in each locomotive having similar equipment. Separate harnesses shall be provided for major circuit groups or types, or as required for specified circuit separation. All circuits and branches shall be separated by means of terminal boards to isolate portions from others for troubleshooting and searching for undesired grounds. All circuits subject to periodic high potential tests shall be so arranged that they can be conveniently set up for the tests.

Alternative methods for fabricating and installing wiring, which are standard Contractor practice, shall be considered for approval by SEPTA.

Harnessed wires shall not be installed in conduit. Wires from different conduits or other openings shall not be harnessed together with wires running within the box or entering the box through another entrance point. Each harness or group of wires between equipment enclosures shall contain a minimum of 10 percent spares, but no less than one spare for each wire size whichever is greater.

15.23.2.2  Circuit Separation

Circuits shall be physically separated to reduce the possibility of unsafe conditions, interference, or equipment damage.

The following major circuit groups shall not be harnessed or bundled together, shall not run in the same conduit, and shall be physically separated and secured in enclosures, wire ducts, junction boxes, or other wire routing devices:

- High voltage circuits,
- AC circuits,
- Communication circuits,
- Battery voltage level circuits,
- Semiconductor gating voltage level circuits, and
- Conductors carrying in excess of 100 Amperes.

Wires which are connected in circuits with potentials differing by 50 Volts or more shall be separated by a physical barrier. The wires shall not be cabled together and shall not be placed in the same conduit, junction box, or enclosure. Where a raceway, duct, junction box or enclosure is divided into two or more
distinct areas by metallic partitions, each area may be considered separately in the application of this rule.

Where it is impossible to avoid having wires at different voltages in the same equipment enclosure, the wires shall be physically separated, bundled, and secured separately such that contact between wiring is not possible. All wiring within an enclosure shall be insulated for the highest voltage in the enclosure, unless approved otherwise. All wiring connected to a piece of apparatus shall be insulated for the highest voltage connected. Wiring connected to transient-generating apparatus, such as unsuppressed contactor coils, shall not be run adjacent to wiring carrying signals to, from, or between semiconductor circuits, logic circuits, vital no-motion circuits, or communication circuits. In cases in which adequate physical separation is impossible, shielded wire shall be used for all conductors involved.

15.23.2.3 Wire and Cable Runs

Wire runs shall be continuous and unbroken between connection points, shall be supported at no greater than 2 foot spacing, and be protected at each support point against mechanical crushing and abrasion. A watertight bushing and drip loop shall be provided on all exposed cable entries. All cable bundles and wires shall be routed a minimum of 1 inch above the bottom of equipment enclosures.

All undercar wiring smaller than AWG No. 6 shall be run in closed wire ducts, conduits, or open wire mesh wireways in an approved manner. Wire and cable shall be secured within ducts or open wireways, including each entrance and exit point, to prevent chafing movement. Wire ducts and conduits shall be of waterproof construction. Permanently retained watertight strain relief bushings, with insulated throat liners, of an approved design, shall be used at locations where wires, cables or harnesses enter or exit conduit, ducts, apparatus and equipment enclosures. In addition, strain relief bushings on equipment enclosures shall include a permanently retained O-ring type seal.

Lead wires to resiliently-mounted electrical apparatus shall be carried in conduit to a point as close to the apparatus as possible. The length of the leads between the end of the conduit and each piece of apparatus shall be as approved. Short runs of cables or harnesses entering or leaving conduit and apparatus shall have an approved guard mounted to the locomotive body to protect the wires from mechanical damage. Lead wires to solidly-mounted, electrical apparatus and equipment enclosures shall run in conduit connected to the apparatus or enclosure.

All wiring routed from enclosed areas of the carbody to areas exposed to the elements (including underframe and roof areas) or between interior levels shall be run in ducts or conduit. Wiring, even if enclosed in loom, must not be run through partitions without suitable bushings being provided at such points of passage.

Cables shall be laid in place with sufficient slack at the bends so that cables shall clear the inside bend surface of the wireway/wire duct.

All wire and cable shall be free of kinks, insulation damage, insulation abrasions, and nicked strands. Wire installation shall not be subject to accumulations of water, oil, or other foreign matter.

Wires or cables shall not pass through or over the battery compartment and shall not pass over heat generating equipment such as acceleration and braking resistors, even if the wires or cables are in conduit.
Exposed harnesses, short cable runs or harness entering or leaving exposed raceways shall have approved, fire-resistant flexible dielectric sleeving over the raceway edges and grommet-type insulation of any penetration holes. Wiring shall be retained to the sleeving with tie-wraps.

1. Cable Cleating and Support

All cable and wiring exiting wireways/wire ducts, or that which is not installed in conduit, shall be cleated using split-block cleats of molded neoprene rubber, fabricated plastic or fiberglass with neoprene cushion inserts. In no case shall nylon wire ties be used as the means of supporting the weight of wire bundles and cables. Cables shall be cleated and bushed when passing through bulkheads and structural members. The cushioning material shall be non-conductive, fire retardant insulating material with a durometer of 50 to 60 meeting the requirements of Section 15.9. Each cleat shall have a stiffener of at least 10 gage material on the side away from the mounting bracket which shall act to spread the bolt clamping force over the entire length of the cleat. Bolts shall have lock nuts. The Contractor shall minimize the quantity of different configuration cable cleats.

AWG No. 6 or larger insulated wire may be cleated in place without conduit, duct or open wireway. However, in the areas over the truck, in the wheel wash and not protected by underfloor-mounted equipment, the wire shall be mechanically protected by an open mesh, expanded metal or other type of approved guard. The guard may be attached to the bottom of each cleat with the cleat clamping bolts or other approved arrangement.

Cleats shall be designed to grip each cable individually and firmly, but without causing any damage to cable insulation, including cold flow of the insulation. Each cable in the cleat shall have its own cutout sized to the correct wire diameter. Cleated cables shall be routed and supported such that they cannot, under any combination of forces and locomotive movement, touch each other or any other part of the locomotive, except the cleat cushioning material.

Wire and cable runs shall be continuous and unbroken between terminations and shall be supported at not greater than 24 inch intervals in ducts, open wireways or when cleated. The wire shall be protected at each support point against mechanical crushing and abrasion.

Wire splices shall not be permitted, except with express written approval and in accordance with the wire splicing requirements of Section 15.23.13.

Concealed wires, such as within conduits and wire ducts, shall be such that wires may be replaced or added to without the removal of other than access panels. It shall not be necessary to disconnect or disassemble conduit to accomplish this task.

Wiring run in loom shall not be carried over a potential chafing hazard. Wires entering any removable box shall be harnessed and secured to facilitate removal of the box.

All wires and cables shall be fully protected against any contact with any surface other than that designed specifically to support or protect them. This applies to all current carrying wires, cables or buses on the vehicle.
2. Wire Securement and Termination

All wiring shall be secured and protected against movement, chafing, and any contact with conductive, sharp, or abrasive objects including the inside surfaces of wire runs.

All wiring shall be located and secured such that normal equipment motions, maintenance access, heat sources, and the environment do not damage or reduce the life of the wiring. Junction boxes, with terminal boards, shall be used, as required, for wire terminations. Harness connections to the boxes, as well as internal wiring to terminal boards, shall be as specified in Section 15.23.2. Exterior junction boxes shall be weather tight.

In cases where it is necessary to anchor wires or cables to metallic parts of the locomotive, cleats or approved stainless steel bottle clamps shall be used. Wires and cables shall not be allowed to chafe or rub against any part of the locomotive or each other under any circumstances.

Wire and cable dress shall allow for sufficient slack at equipment terminals to provide for movements induced by shock and vibration, equipment shifting, alignment, cover removal and component replacement. Sufficient lengths shall be provided at points of termination for additional reterminations without applying tension to the wire and without splicing the wire, as follows:

- AWG No. 10 and smaller - Three reterminations
- AWG No. 8 and larger - Two reterminations

A drip loop shall be provided on all exposed wires and cables to prevent fluid runoff into connected equipment.

Spare wires, which are part of a wire harness, shall be bundled separately inside of the equipment box to which the harness is being terminated. Spare wires shall have enough length to reach any location within the box, including sufficient slack for the required number of reterminations. The spare wire “break-out” bundle may be ty-wrapped to the main harness, but shall be easily removed from the main harness without disassembling it. The ends of the spare wires shall be insulated against inadvertent contact with any nearby conductive surfaces or terminals. Each wire routing shall have a minimum of 10% spare wire runs.

Wire tying devices shall be of such material and construction that they shall adequately retain the wires for the life of the wiring and shall be resistant to ozone and ultraviolet light. Wire and cable ties shall be trimmed and located to eliminate any hazard to personnel from sharp edges. Wire tying devices shall be snug, but shall not be so tight as to cause indentation and cold flow damage to the insulation. Wire tying devices shall be mechanically fastened to a permanent structure. Adhesive-installed mounting bases shall not be used for ties or for cable support.

All wire bundles and cables within an enclosure shall be supported by the use of tape rails, shall be spaced away from the equipment box structure, metal edges, bolt heads, and other
interference points, and shall have electrical clearance from the covers, regardless of the insulation properties of covers. Wire bundles shall be located above or alongside the apparatus rather than at the bottom of the box wherever possible. In all cases, wire shall be a minimum of 1 inch above the bottom of the box, unless otherwise approved by SEPTA. Wire entry into control or junction boxes shall not be permitted through the bottom of the box.

Truck wiring shall be designed to ensure sufficient slack, and shall be provided with clamp supports and abrasion protection. T-splices shall not be permitted.

All jumpers, jumper heads, and jumper receptacles shall be sealed in an approved manner to prevent the entry of water at any operational speed of the locomotive.

Any wiring needed to calibrate and test locomotive functions shall be a part of the permanent locomotive wiring to enable SEPTA to conveniently maintain the equipment. This wiring shall terminate in approved connectors in the respective control groups and cabinets.

SEPTA desires to have wiring and cabling readily accessible for inspection and maintenance. Extensive wiring and cabling in the vehicle interior is contrary to accessibility, even though access panels, false floors, and other portals may be provided. To control this, the Contractor shall submit a complete wiring plan for approval.

Wire and cables that are subject to high currents in fault conditions or normal operation must be secured against secondary damage due to the high magnetic forces that are developed. Propulsion inverter circuits are a typical example. This includes damage to bus bars or devices to which the cables terminate.

15.23.2.4 Circuit Shielding

Wire shields used in trainline circuits shall be continuous up to the locomotive’s electrical coupler contacts, including contacts of the jumper cable connector at the intermediate couplers. The wire shields shall be connected through all applicable connectors and junction boxes. Circuits shall be categorized. Shields contained in one circuit category shall not be interconnected with shields contained in another category. Shields used to protect against interference shall not carry signal current.

Shields on low-level signal wires shall not be interconnected with shields on high-level signal wires in the same category. Each group of shields (other than at the electric couplers, including the jumper cable connectors at the intermediate coupler) shall be carried through on a connector pin or pins, or on terminal strips which shall be in the immediate proximity of the categorized group of circuits. Loops due to interconnections of shields shall not be permitted.

Coaxial cables used as constant impedance transmission lines shall be terminated as dictated by the circuit termination design and shall not be considered to be shielded conductors. Triaxial cables may be used as coaxial impedance transmission lines with the outer conductor employed as an RF shield.

The following three items shall be considered as guidelines and are not absolute requirements:
• Shields used to suppress electromagnetic interference (EMI) at all frequencies shall be terminated only at the low potential side of the interference circuit, at the termination which exhibits maximum susceptibility.

• Shields used to protect against the effect of, or to exclude, EMI at frequencies below 150 kHz, shall be terminated either to the low potential side or at the balance point of the protected circuit at the termination which exhibits maximum susceptibility.

• Cables requiring both audio frequency (AF) and radio frequency (RF) shields shall be electrically isolated from each other. The resistance between these circuits shall be at least 500 megohms when 500 VDC is applied. Double shielding shall be required on circuits that are both AF-susceptible and RF-susceptible.

### 15.23.3 Insulation Resistance

Refer to 18.22.3 for insulation resistance requirements.

### 15.23.4 Marking and Designation

The Contractor shall devise, and submit for approval, a wire and terminal marking and designation system that shall coordinate all electrical circuits in the locomotive into a unified system.

The system shall identify all wiring, including circuit return wiring, and terminals according to their respective circuit function(s) and shall accurately correlate these designations with the locomotive schematic diagrams. Each circuit shall be individually designated from point to point. Common designations for return circuits are not permitted.

Each wire and cable shall have printed on the outer surface, the manufacturer's identification, conductor size, temperature rating, and voltage rating. For wire size 1/0 and larger, stranding shall be given in addition to the other parameters.

Except for spares, TFE Teflon insulated wires and wires entirely within an equipment enclosure, each wire #8 AWG and smaller shall be permanently and legibly marked along its entire length. Wires larger than #8 AWG and TFE Teflon insulated wires may have wire markers applied at each end of the wire. Blank spaces between markings shall measure approximately 1.5 inches. Spare wires and wiring entirely within an equipment enclosure may have a single wire marker at each end, subject to approval by SEPTA in lieu of continuous marking. Wires shall be marked with their alpha-numeric circuit designation. A circuit designation shall change only when it goes through an active or passive component such as a relay coil or relay contact, fuse or circuit breakers, lamp, motor or resistor. A circuit designation shall remain unchanged when it goes through a terminal strip or junction box stud regardless of how many wires of that circuit are common to that point. There shall be no duplication of wire codes in unrelated circuits throughout the locomotive. Where there are more than one of a particular assembly per locomotive, each assembly shall be wired identically to the other(s) and wire marking of harnesses shall be identical in each assembly.

For pre-manufactured multiconductor cables and for cases where individual circuit identification markers may be approved the following requirements apply:
All wires and terminals shall be clearly identified. Wires attached to terminal studs shall also have a marker indicating the terminal stud to which it is attached.

Identification of wires and terminals shall be by white or yellow permanent markers, with black printing or by continuous wire marking printed on the wire. All wires shall be marked 6 inches from the end of the wire (both ends) and every 24 inches over the remainder of the wire. Wire markers shall be stamped in two places, approximately 180 degrees apart, to facilitate readability of the marking. Wires in multiple-conductor cables shall be color-coded.

Wire markers shall meet the adherence and solvent resistance requirements as specified by MIL-M-81531 Sections 3.4.2 and 3.4.3, latest revision, and shall withstand all combinations of ambient and equipment temperatures. Hand printing is prohibited.

For cable identification, the contractor shall submit the system selected for review by SEPTA.

**15.23.5 Pulling Compound**

Pulling compound shall be non-conductive, non-hygrosopic, non-odorous, shall not support bacterial activity, and shall not attract vermin.

**15.23.6 Solder**

Solder shall be in accordance with ASTM B32, Grade Sn60. A flux of non-corrosive type shall be applied immediately before soldering.

**15.23.7 Tape**

Electrical tape shall be in accordance with AAR Standard S-540 of Section F of the AAR Manual Standards and Recommended Practices, or equivalent approved railway practice. Electrical tape shall meet or exceed the voltage rating of wire where the tape is applied.

**15.23.8 Terminal Boards & Terminal Points**

Electrical terminal points and terminal boards shall have brass studs and connections, each of which shall be locked using a single brass nut with brass flat washer and a plated spring-type lock washer. Studs, nuts, and washers may also be made of corrosion-resistant, plated steel, where approved. Each board or connector shall have the necessary number of terminations plus a minimum of 10 percent spares, but not less than one spare unless approved. Binding head, screw type terminal boards shall be permitted only where approved. Terminal boards of this type shall be in accordance with Military Specification MIL-T-55164A.

Threaded studs shall have a minimum of 2-1/2 threads exposed beyond the final nuts. Adequate space shall be provided to permit connecting wire terminals with standard tools. All terminals shall be properly torqued to assure sound connections. Spacers shall not be used.
A maximum of two terminals shall be connected to any one binding screw. A maximum of four terminals shall be connected to any one threaded stud, provided that there is no interference between terminal barrels. On terminal boards, the wiring shall be arranged so that no more than two terminals are connected to a stud, from each side of the terminal boards.

Molded case, modular terminal blocks which utilize a spring clamp to hold the wire may be used for low voltage circuits. Each terminal block shall be properly identified with a permanent marking and each assembly shall be secured to the mounting (DIN) rail by end clamps which incorporate metallic hardware. All wires AWG 12 and smaller shall receive a ferrule. Plug-in style (split) terminal blocks shall only be permitted if, as part of the design, these plugs shall be used as a connector when performing maintenance, testing or replacement of a Line Replaceable Unit. All molded case, modular terminal blocks are subject to review and approval by SEPTA.

Jumpers between terminal board points shall be brass or plated steel. Wire jumpers between adjacent terminals of terminal boards shall not be permitted.

An approved permanent marking strip on each terminal board shall be provided and attached adjacent to the wire junction point to identify the wires attached thereto and/or the wires connected to terminal boards shall have the terminal point location printed on the wire.

### 15.23.9 Wire Terminations

Terminals and connections used throughout the locomotive shall be the mechanical, solderless, crimp type made by AMP Incorporated or other approved manufacturer with a comprehensive line of terminals, connector pins, and application tools available. All terminals for the same wire size shall be crimped with the same model tool. The Contractor shall minimize the total number of crimping tool types needed for all crimp connections. Terminals fitting wire sizes AWG No. 10-22 shall require no more than three tool models to provide certified crimp connections. The Contractor shall submit the proposed product line for approval. Terminals to be approved shall be tested to Military Specification MIL-T-16366F for temperature rise, voltage drop, vibration, current overload, and corrosion. Test results shall be submitted for approval on a by part number basis.

Terminals and connections shall be attached to the wiring with proper crimping tools and dies as recommended by the manufacturer. The terminals used on conductors of size AWG No. 10 or smaller shall be of the type which securely grips and holds the insulation of the conductor, unless approved. Terminals shall be ring lugs in accordance with Military Standard MS-25036.

For components that do not accept ring tongue terminals, appropriate alternate terminations such as ferrules, locking forks or quick disconnects may be used subject to approval by SEPTA. Corrosion protection shall be provided for all base materials.

Conductors subject to motion relative to the terminal shall be protected by suitable means to prevent breakage of the conductor at or near the terminal. Sufficient slack shall be provided in all wires and cables to prevent breaking or pulling out of bushings and terminals. A maximum of one wire shall be crimped in any one terminal.

Wherever several wires are connected to terminals of a terminal strip on a device which is removable from the locomotive for maintenance, the wires shall be terminated, with double ring terminations.
which shall be screwed to an insulating fanning strip which shall serve to keep the terminations in the correct relative locations while removed from the device, unless otherwise approved by SEPTA.

### 15.23.10 Power Cable Terminations

Power cables shall be terminated with an approved compression terminal. Sufficient cable slack shall be provided to preclude breaking or pull-out from bushings or terminals and to allow two terminal changes. Cable conductors shall be clean prior to installation of terminals.

Compression terminals shall be applied using tools and procedures recommended by the terminal manufacturer for that purpose. Swaging tools shall be of a type that ensures complete swaging in every case.

### 15.23.11 Cable Connectors

All cable connector applications shall be approved.

All cable connectors shall conform to MIL-C-5015 or an equivalent standard as approved. They shall employ removable crimp contacts of the correct size for the wire being terminated. Except as noted below, the connector contact area shall be plated with a minimum of 0.000030 inch of gold over a minimum of 0.000050 inch of low stress nickel. For high current applications, the connector contact area shall be plated with a minimum of 0.00010 inch of silver. Adjacent connectors shall either use different inserts or different insert orientations to prevent erroneous connections. The receptacle half of all cable connectors shall be rigidly mounted.

All cable connectors used in exterior locations shall be of the environmental watertight variety. Cable connectors shall be equipped with sealing gaskets on the front mating surface and on the back where the cable enters. The cable jacket shall be held by a clamp within the connector body. Unused connector pin positions shall be sealed with either connector contacts or plastic sealing plugs designed for that purpose.

Plastic bodied connectors shall not be used in exterior locations. Quarter turn, bayonet-lock, quick-disconnect type connectors shall not be used on trainline jumper cables.

Except as specified above all cable connectors in exterior locations, shall be quarter turn, bayonet-lock, quick disconnect type CIR connectors as made by Litton-Veam SPA, or approved equal. Quarter turn, bayonet-lock connectors shall conform to all provisions in MIL-C-5015, or an approved standard, except for the screw coupling requirement.

Connectors in high vibration or high motion areas, such as speed sensors and trainline jumpers, shall have the wire connections soldered and potted and shall have a watertight jacket molded over the cable and connector to form a unitized assembly. Trainline jumper connectors used shall be as made by Pyle-National, or approved equal. The Contractor shall conduct an approved vibration test on these unitized assemblies.

Non-metallic body, non-environmentally sealed connectors are limited for use on non-vital, interior applications, such as lighting and speaker connections. These connectors must be threaded or include a
positive locking mechanism. All such connectors must include a suitable means of strain relief for the wires. If a spring-clamp is used to terminate the wire within the connector body, a properly sized ferrule must be applied to the wire. The receptacle half of each connector assembly shall be rigidly mounted. Proposed connectors shall have a minimum of 2 years of successful service in similar applications and are subject to approval by SEPTA.

15.23.12 Grounding Return Connections

15.23.12.1 Grounding

Grounding connections to the locomotive body and equipment shall be made through copper pads of an adequate area, silver soldered or brazed. Alternative ground pad material may be permitted in certain cases as approved by SEPTA. Transition (base) plates if used, shall be made from the same alloy group as the respective locomotive body and piece of equipment. The base plate shall be welded to the locomotive body or equipment. Grounding connections shall not be made to aluminum alloy members. All ground pads shall be visible and accessible for inspection and troubleshooting. The ground connections shall be attached by a bolt, washer, and nut designed for the purpose. An anti-corrosive grease shall be applied over the connection.

All equipment enclosures and shock-mounted equipment, except the operator cab lights, shall be grounded with flexible, grounding leads bolted between a locomotive body grounding pad and the equipment's grounding pad. Braided, strap-type leads shall be used where there is relative motion between the two items being connected. The ground strap termination method shall apply uniform pressure to the conductive surface.

The Contractor shall design a complete grounding scheme, which shall indicate the means by which it is proposed to prevent currents from passing through journal and truck-center bearings. Refer to other sections of this Specification for ground brush and related requirements. Low voltage and high voltage circuits shall not be grounded to the same ground.

15.23.12.2 Bonding

All grounding and bonding jumpers and straps shall be sized to handle fault current and lightning discharge current, for which the voltage drop shall not exceed 25 Volts. The bonding method employed shall not produce a DC resistance in excess of 0.0025 Ohms, or more than 0.025 Ohms at 150 kHz for any applied AC voltage. Grounding and bonding jumpers, and brazed shunt straps shall be "extra-flexible".

15.23.13 Wire Splicing

Splicing of conductors shall be avoided and shall be permitted only with approval on a case-by-case basis. Splicing of conductors in conduit shall not be permitted. In the event a splice is approved, it shall be in a junction box and the spliced joint shall be mechanically as strong and have the same conductivity as any other part of the conductor. The splice shall be an insulated permanent crimp splice in accordance with Military Specification MIL-T-7928G, Type II, Class I, and shall be installed with the crimping tool and die of the splice manufacturer. All splices shall be insulated with a self-sealing, weather-tight, seamless shrink tubing. The outside diameter of the spliced portion of the cable after the
insulation is applied shall not exceed the outside diameter of the un-spliced portion by more than 40 percent. Splices shall be identified in the integrated schematic.

### 15.24 WIREWAYS, CONDUIT, JUNCTION BOXES, AND FITTINGS

#### 15.24.1 General

The conduit, conduit fittings, and junction boxes for locomotive wiring shall be as manufactured by the Contractor or by a supplier of a comprehensive line of parts. The Contractor shall submit the proposed product line for approval. All conduit fittings and junction boxes shall be provided with gasketed covers as described in Section 15.24.4. All conduits and their connections to electrical equipment shall be installed to make a continuous ground.

#### 15.24.2 Conduit Types

All conduit and conduit couplings shall be of an ANSI-approved type. All conduit shall be standard weight, galvanized steel with threaded fittings. All conduit ends shall be deburred inside and out to remove sharp edges and all pieces shall be blown out with compressed air and cleaned before installation to remove filings and other foreign material.

Steel conduit shall be mild steel in standard lengths with threaded ends and hot-dipped zinc-coated exterior and interior surfaces. It shall be free of burrs and projections, circular in cross-section, of uniform wall thickness and shall conform to the requirements of ANSI Standard C-80.1. The threads per inch and length of threading shall conform to ANSI Standard B-2.1 on pipe threads.

Steel fittings shall be used to assemble steel conduit. Elbows, nipples, and couplings shall be made of the same grade of steel as that employed in the conduit. All fittings shall be treated, coated, and threaded according to the requirements for zinc-coated, rigid steel conduit and shall conform to UL 6.

Thin-walled, Electrical Metallic Tubing (EMT) or aluminum conduit shall be permitted for interior use only. All applications of such conduits shall utilize compression-style connectors and couplings.

Flexible conduit, if used, shall be watertight and interlocking aluminum such as Anaconda seal tite or steel strip-protected, with an approved rust resistive coating. Flexible covering on conduit shall not contain polyurethane or PVC vinyl.

Liquid tight flexible nonmetallic conduit, if required for special applications, may be used with SEPTA's approval. Liquid tight flexible nonmetallic conduit shall not be used where subject to physical damage or in lengths longer than 6 feet.

Conduit shall be color-coded: red for those carrying circuits above 100 Volts and yellow for under 100 Volts.
15.24.3 Junction Boxes

All exterior junction boxes shall be fabricated of minimum 14 gauge steel or aluminum. All exterior junction boxes shall be weatherproof and shall be connected in such a way that drainage from equipment groups shall not pass through conduit into the junction boxes. Interiors of all junction boxes shall be primed and then protected with a white, insulating coating as specified in Section 15.17.4.

15.24.4 Covers

All junction box covers shall be dust proof, retained by compressive spring-type latches, or captive screws as approved on a location-by-location basis. All fasteners used in junction boxes shall be stainless steel. All covers shall be designed to accept or mate with a bulb-type clamp-on seal.

15.24.5 Wireways

Wireways shall be permitted in approved exterior and ceiling locations only. They shall not be permitted in the locomotive body sidewall area. Only conduit shall be permitted in the locomotive body.

All wireways shall be of rigid, stainless steel construction. Wireways shall be color-coded; red for those carrying circuits above 100 Volts and yellow for fewer than 100 Volts. The trays shall be adequately supported throughout their entire length in an approved manner. The trays shall be completely de-burred, leaving absolutely no sharp edges, before installation on the vehicles. Grommet clamps shall be provided at all locations where cables or wires enter or leave the wireways. Under no circumstances shall leads be draped over the edge of the wireways, with or without wireway edge protection. Heads of screws or bolts inside the raceways shall be flush with the metal surface. Metal wireways, elbows, couplings and similar fittings shall be flush with the metal surface. Points of screws or fasteners shall not be directed toward the interior of wireways. Removable wireway covers shall be secured with captive fasteners.

Wireways shall be designed to prohibit the collection of dirt and debris, and shall be perforated, without compromising their requisite strength, to permit ventilation and drainage. They shall preclude water entrapment.

15.24.6 Conduit Interface

The open ends of conduit shall be provided with strain relief type fittings with extended rubber bushings, bell-mouth fittings, or insulated throat box connections as approved. All conduit entries into removable equipment boxes shall be secured by means of a bolt-on watertight access panel.

15.24.7 Size and Fill

Conductor area, including wire, insulation, and jacket shall not exceed 40 percent of the interior cross-sectional area of the conduit unless approved by the authority, but in no case should exceed 60 percent. Where conduit having a length not exceeding 24 inches without bends of more than 15 degrees is used between enclosures, a maximum fill of 60 percent shall be permitted.

Wireways shall not contain more than 30 current-carrying (i.e., power source as opposed to signaling) conductors at any cross-section. Conductor area, including wire, insulation, and jacket shall not exceed
40 percent of the interior cross-sectional area of the wireway unless approved by the authority, but in no case should exceed 60 percent.

15.24.8 Installation

15.24.9 Conduit

A run of conduit between junction boxes and/or pulling outlets shall not contain more than the equivalent of four quarter bends, 360 degrees total, including the outlet fittings. Bend radii at the inner surface of the bend shall be no less than eight times the nominal inside diameter of the conduit.

All conduit bends and offsets used shall be made by the use of special forms or tools and shall have the largest radius possible so that wires can be pulled without the use of tackle or power.

Conduit shall be securely clamped with all runs electrically grounded to make a continuous ground. Conduit installation shall not create situations of dissimilar metals.

All conduit shall be arranged to prevent moisture traps and shall drain toward control boxes, except that all open-ended conduits shall be installed in such a manner as to ensure gravity drainage out the end. The conduit arrangement and installation shall be subject to approval.

15.24.10 Wireways

Wireways shall be located to provide access to the harnesses contained within for maintenance action. They shall be provided with approved covers which may be interrupted wherever desired for entry and exit of wires and cables. Edges of such interruptions shall be completely covered with protective bushings.

The wireways shall be routed such that they avoid:

- Sources of heat such as propulsion and dynamic brake grid resistors;
- Wheel splash areas; and
- Areas along the vehicle where the trays may be subject to foreign object damage.

Metal raceways and the elbows, couplings, and similar fittings shall be electrically and mechanically coupled while protecting wires from abrasion and shall make a continuous ground with the locomotive structure.

Bends in wireways shall be avoided; however, if they are required, approved protection shall be provided to avoid insulation chafing at the bends.

All wire and cable shall be securely fastened within wireways to eliminate movement and resultant chafing.
15.25  ELECTRICAL DEVICES AND HARDWARE

15.25.1  General

All electrical devices shall be transit industry-proven.

15.25.2  Contactors and Relays

All contactors and relays shall meet or exceed the requirements of MIL-R-6106 and MIL-R-5757 respectively, with the following qualifications:

- Devices shall be tested for proper functioning in orientations up to 30 degrees from the orientation in which they are mounted in the vehicle, in each of the three possible rotations: pitch, yaw, and roll.

- If adequate documentation exists demonstrating that during functional and operational testing of the vehicle the contactors underwent normal duty cycle tests, it shall be considered as an acceptable alternative to a burn-in.

- In selected applications, contactors and relays shall comply with the requirements of MIL-R-6106 (for ratings of 10 Amperes or greater) and MIL-R-5757 (for ratings of less than 10 A) but need not be qualified to these documents if all of the following requirements are met:
  - The device is service proven in the exact same application.
  - The device is service proven in transit service.
  - All other requirements of this Specification are met.
  - SEPTA approves of this application.

All devices shall be constructed and utilized in a fail-safe manner; that is, all failures shall be in a direction so that neither the passengers, the crew nor the equipment are placed in jeopardy.

All devices shall be installed so that they are fully accessible for inspection, repair-in-place, or removal and replacement. All contactor terminals shall be fully accessible for trouble shooting purposes. Contactors and relays shall incorporate means of visually determining whether they are picked up or dropped out. Relays on printed circuit boards or within electronic assemblies may be exempted from the requirement for a visual indication, as approved by SEPTA.

There shall be a maximum of two wire terminations on any one contact of the device.

The coils of all devices shall be suppressed to protect the low-voltage network from generated transients.
Under no circumstances shall either the main or auxiliary contact tips of the devices be placed in parallel for the purpose of carrying a current load at or above the manufacturer’s contact tip rating.

Contact tip ratings shall be stated for the worst condition of reduced surface contact which may result from tip misalignment during normal operation of the device.

Contactor installation shall be such that the arc spray is directed by an arc chute away from ground and any other electrical devices proximate to the contactor.

Devices shall be constructed in a very heavy-duty fashion suitable for use in railroad service. SEPTA reserves the right to review and approve the design and selection of all contactors and relays.

Contactor tip replacement shall not exceed 10 percent of the total number of tips at ninety (90) day intervals.

All contactors shall be constructed so that the main contact tips make and break with a motion (wipe) that prevents deposits and pitting.

All DC contactors shall be built with series-fed blowout coils. The Contractor shall demonstrate the ability of each contactor type to reliably interrupt current over the full design operating range.

All devices shall be readily identifiable by means of a permanent, durable marking strip giving the device circuit designation. No identifications shall be obscured, or partially obscured, by wire routing. The identification strip shall be mounted adjacent to the mounting of said device.

Bifurcated contacts shall be used in low voltage applications, whenever necessary due to dry contacts or low current switching requirements.

All time delay relays shall be of the R-C delay or solid state type. No mechanical or pneumatic time delay devices shall be permitted.

Where plug-in relays are approved, the relay shall be positively retained by means of a retaining clip or bar. This device shall be captive, of rugged construction and shall be easily positioned for relay installation and removal without the need for special tools. When the relay is removed, the retainer shall itself be retained so that it cannot come in contact with devices which may have exposed energized electrical circuits, and it shall not interfere with the operation of any other device when in this position.

Adequate gap and creepage distances shall be maintained from high voltage contactor tips and low voltage coil and auxiliary contacts to prevent entry of high voltage arcs or transients into the low voltage circuits. The same applies to grounded mounting surfaces.

Relays shall not be affected by the accumulation of airborne dust.

### 15.25.3 Switches

Under no circumstances shall poles of switches be placed in parallel in order to carry currents in excess of the contact pole rating given by the manufacturer.
Switches shall be provided with a "keying" feature so that after installation, the body of the switch is constrained from mechanical rotation.

All switches provided shall be of the highest quality procurable and shall be fully suitable for the rigors of SEPTA's service environment. All control switches which are subject to water splash, which is defined to mean any switches mounted near windows or doors, or mounted on the Train Operator's control console, shall be environmentally sealed. Toggle and push button switches shall be per MIL-S-3950, MIL-S-8805, MIL-S-83731, or equal. All safety-critical switches, such as those that can cause door openings, shall be designed to withstand a high potential test of 1,500 Volts for 1 second, in a clean, dry condition, without false conduction. The design and selection of all switches shall be subject to review and approval.

There shall be a maximum of two (2) wires connected to each terminal of the device.

Switches shall be individually replaceable without disconnecting or removing anything other than the mounting fasteners and electrical connections of the switch to be replaced.

In addition to the above requirements, all switches and pushbuttons shall meet the following requirements:

- Contact resistance shall be less than 0.1 Ohm at 3 VDC and a 10 milliampere load.
- Open circuit resistance shall be 50 mega Ohms minimum.
- Resistance to case shall be 1000 mega Ohms minimum at 500 VDC.

15.25.4 Circuit Breakers

15.25.4.1 General

All circuit breakers provided shall be extremely rugged and fully suitable for the service intended.

They shall be of the highest quality procurable. Design and selection of all circuit breakers shall be subject to review and approval.

All circuit breakers of the same rating shall be of the same manufacture and model throughout the vehicle.

The “ON”, “OFF”, and “TRIPPED” positions of all circuit breakers shall be permanently marked on the handle or the case of the circuit breaker. The circuit breaker, when tripped, shall assume a distinct position between the “ON” and “OFF” positions to permit determination of the fact that it has been tripped by either its over-current or shunt trip elements. All circuit breakers shall be mounted in the vertical direction with the “ON” position up.

Circuit breakers shall be individually replaceable without disconnecting or removing anything other than the mounting fasteners and electrical connections of the breaker to be replaced.
Electrical connections to circuit breakers shall either be threaded to accept machine screws or use a threaded stud. Wires to circuit breakers shall use ring terminals.

Circuit breaker terminals shall not be used as junction points.

Each and every input power circuit shall be protected by an individual circuit breaker. Separate circuit breakers shall be provided for major assemblies or functions. No circuit breaker shall protect more than one circuit, nor shall any one circuit be protected by more than one circuit breaker.

All circuit breakers shall be sized by current rating and tripping time to protect both the associated equipment and the minimum size wire used for power distribution within the protected circuit without causing nuisance tripping.

High voltage circuit breaker poles may be connected in series if necessary to achieve the stated voltage interruption requirements.

Each circuit breaker pole shall be equipped with adequate means of arc extinction to prevent flashover.

The continuous current rating of thermal-magnetic trip circuit breakers shall be selected in accordance with ANSI C37.16 for the load and type of service specified.

All thermal-magnetic trip circuit breakers shall conform to the requirements of ANSI C37.13 and ANSI C37.14.

Circuit breaker current rating shall be clearly and permanently marked and shall be completely visible after installation.

Electrically operated circuit breakers shall be arranged for operation from the low voltage dc supply.

**15.25.4.2 High-Voltage Circuit Breakers**

All high voltage circuit breakers shall be devices with not less than 3 poles connected in series.

All distribution-type, high voltage circuit breakers shall be Westinghouse Series C, FDB frame, Heinemann type GH, or approved equal.

The trip elements shall be thermal-magnetic, or magnetic, connected in series.

The circuit breaker handle shall protrude from the circuit breaker panel cover sufficiently to be manipulated in all positions.

**15.25.4.3 Low-Voltage Circuit Breakers**

Low voltage circuit breakers shall be either one-pole or two-pole devices depending on the intended function. Trip elements shall be thermal-magnetic, or magnetic, as is appropriate for the application.
All low voltage circuit breakers shall be:

- General Use - Westinghouse Series C, Quicklag C frame, Heinemann Series AM or approved equal, front connection or approved access arrangement, and approved labeling.

- Fast Operation - Airpax type IMLK, dust sealed, magnetic breaker, or Airpax type UP, hermetically sealed, magnetic breaker, or an approved equal.

### 15.25.5 Fuses

Fuses shall be used only where specifically called for in the Specification or where the use of circuit breakers is not technically feasible, and only with specific approval. Fuses may be considered in applications as follows:

- To protect solid state equipment from catastrophic damage, and

- Where current or voltage levels prohibit circuit breakers.

Fuses shall be permanently identified adjacent to the fuse. The rating of each fuse shall be permanently and clearly marked directly on each fuse.

Fuses shall be readily accessible. All fuses mounted in exterior equipment boxes shall be accessible without going under the vehicle.

Fuse holders shall contain fuse retention devices at both ends.

Air gap and creepage distances shall be as approved. Fuses used in nominal 600 VDC circuits shall be rated for no less than 1,000 VDC.

High voltage fuses shall be mounted in totally enclosed, dead front fuse holders, with no exposed high voltage connections. The fuse shall be extracted from the circuit when the fuse holder is opened and the exposed fuse shall be safely isolated from any circuit connection.

Where circuits use multiple fuses or fuses and circuit breakers, the coordination between the protective devices shall be discussed in design review.

### 15.25.6 Bus Bars

Bus bars are to be fabricated from OFE (Oxygen Free Electronic CDA C10100) or ETP (Electrolytic Tough Pitch CDA C11000) copper. The bus bar conductivity shall be 100 percent IACS. All bus bar joints shall be silver or tin plated.

Current densities, other than at joints, shall not exceed 1,000 Ampere per square inch, and in any case shall not exceed a value which would cause a bus bar temperature rise greater than 96°F. Current densities in joints shall not exceed 150 Ampere per square inch.
Bus bars shall be properly brazed together at joints unless bolted connections are found to be absolutely necessary for maintenance purposes and are approved. The overlap at bus bar joints shall be no less than 10 times the thickness of the bus material. Bus bar connection bolts shall be torqued to obtain a uniform bus bar connection pressure of 200 psi. Bolting hardware shall be plated steel with belleville washers to maintain connection pressure.

Except for connection areas, bus bars shall be safety-insulated, using a high-dielectric powder coating, heat shrink tubing or other approved means. Tape is not acceptable. Bus bars that are behind insulating panels are exempt from this requirement.

15.25.7 Capacitors and Resistors

Hermetically sealed, dry tantalum capacitors, in metal cases, shall be used in place of aluminum electrolytics, except for very high values which are not commercially practical or available, in which case long life grade aluminum electrolytics shall be used.

Commutating capacitors shall be a paper or plastic film type, shall incorporate a non-toxic impregnant, and shall be chosen to give a service life of at least twenty (20) years. Filter capacitors shall have high ripple current rating for long life.

Capacitors shall be derated 20 percent for voltage based on the nominal supply voltage and maximum case temperature. If filter capacitors are exposed to low ripple voltages, lesser values of derating may be accepted if it can be shown that reduced operating temperatures can be achieved due to lower dissipation; however, the sum of the DC and AC ripple voltages shall always be less than the capacitor's voltage rating at a maximum case temperature of 185°F.

Except for braking power resistors, all resistors shall be derated 50 percent for power dissipation. Other power resistor applications may be submitted for approval of lower derating, on a case-by-case basis.

15.25.8 Transformers and Inductors

Transformers and inductors shall be derated 10 percent for current. Transformers shall:

- Have vacuum-impregnated windings.
- Be rated to withstand at least twice the maximum peak-to-peak voltage that they shall be subjected to in operation.
- Not emit audible noise in excess of 60 dB referenced to 20 micropascals at a distance of 2 feet while operating at rated voltage and load.
- Be designed to minimize radiated and induced EMI.
- The location, orientation, mounting, cable connections and cable routing shall be in accordance to the overall EMI/EMC control plan for the vehicle.
15.25.9 Switch, Circuit Breaker, and Fuse Panels

All switch, circuit breaker and fuse panels shall be dead front types mounted in the specified equipment enclosures.

Each switch and circuit breaker panel shall carry the necessary apparatus, arranged to be easily accessible to connections and designed to prevent operating or maintenance personnel from coming in contact with live parts when operating the switches or circuit breakers. Furthermore, all live portions of the protected circuitry shall be completely concealed so that no danger of electrocution or shock exists from the touching of the panel or any appurtenances or devices mounted thereto.

All switches, breakers, fuses, and indicating lights shall be provided with a nameplate of raised or recessed lettering on the dead front, clearly identifying the circuit which each controls and its circuit designation. The dead front panel shall conform to NFPA 70, Article 384. The dead fronts shall be made of moisture-proof, electrically insulating, laminated phenolic or fiberglass, of approved quality suitable for switchboards. Asbestos shall not be used.

A wiring gutter shall be provided along the top, sides, and bottom, for the routing of high voltage leads to their designated circuit breakers.

The panel shall be secured by approved, captive fasteners and shall be configured for easy removal so that maintenance and repair action is not impeded.

Power distribution to circuit breakers and switches shall be from a bus bar or bus circuit. Distributing power by successive or "daisy-chained" connections between device terminals shall not be permitted.

15.25.10 Battery Backup Circuits

Backup batteries are not permitted, unless specifically approved by SEPTA.

15.25.11 Auxiliary AC Motors

All AC driven motors shall be of American manufacture. Motors shall limit starting current to within industry recommended practices and 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 minimum life of 6 years.

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.
15.26 ELECTRICAL AND ELECTRONIC DESIGNS

15.26.1 General Design Criteria

Except as otherwise noted herein, electronic equipment shall conform to IEC 60571, Electronic Equipment Used on Rail Vehicles, Class TX, unless otherwise approved by SEPTA.

All low voltage apparatus shall function satisfactorily for any duration at any continuous voltage between 55 and 80 volts, measured at the battery, and shall not be damaged or operate in an unsafe manner by the continuous application of voltages below 55 volts. All hardware shall be protected against moisture, oxidation, and common air-borne contaminants. Use of any locking compounds or anti-seize compounds on threaded electrical connections is prohibited. Conveniently located near any removable printed circuit board, or group of such boards, shall be a primary power switch whose opening shall make it possible to remove and replace such boards without injury to them. This switch may have multiple functions relating to troubleshooting and diagnostics as required. Equipment containing devices that are sensitive to electrostatic discharge (ESD) shall have provisions for hookups, properly identified, for attaching grounding devices. Equipment shall be designed to reduce or eliminate the need or requirement that maintenance crews be grounded during the maintenance of the cars. All circuits on the car shall be designed to impose sufficient current load to positively eliminate any problems from "dry circuit" conditions to the satisfaction of the Engineer.

The need for adjustments shall be avoided wherever possible by the use of appropriate circuitry, stable components, and the use of high tolerance drift compensation and temperature compensation circuits. Where adjustments on printed circuit boards are necessary, they shall be accomplished without the use of specialized (i.e., non-catalog US supplier) test equipment unless this equipment is furnished by the Contractor.

In general, all return circuits for any one system shall return to a single terminal point, without any connections to returns from other systems. Circuit design shall minimize both circuit complexity and number of components and shall annunciate component failures in a safe manner by responding or not responding, as appropriate, to commands for changes of state. Use of diodes shall be minimized and when used their failure shall not allow an unsafe condition to be created.

Electronic equipment shall utilize stock components and shall function properly with the component manufacturer's full range of tolerances such that after-purchase screening or testing of components shall not be required. Matching of components is permitted only if the components are normally available from the manufacturer in matched sets.

Equipment design consideration shall include separation of high voltage from low voltage devices. Components shall not be located near or above high voltage contactors. All low voltage components, controls, circuits and mounting hardware near or in the arc path of contactors shall be adequately protected against damage either by insulating material or by adequate distance.

All fiber optic cables shall be installed in accordance with the cable manufacturer's instructions, shall be adequately protected from damage of any kind, and shall be readily accessible for maintenance and inspection. Fiber optic terminations shall be designed to prevent degradation due to the car environment, including vibration and variation in temperature, and shall be capable of inspection and
repair without removal from the car. Fiber optic cables shall be provided with a minimum of 10 percent spares on a location-to-location basis. Samples and technical details of all proposed fiber optic cables and connectors shall be presented to the Engineer for approval.

Capacitors shall be derated at least 20 percent for voltage based on the nominal supply voltage and maximum case temperature except for the DC link capacitors in the propulsion system which shall be derated at least 10 percent. Hermetically sealed metal-cased dry tantalum capacitors shall be used in place of aluminum electrolytic capacitors, except for very high values which are not commercially practical or available or where otherwise not appropriate, in which case long life grade aluminum electrolytic capacitors shall be used or in cases where tantalum is technically inappropriate. Alternates with equivalent service life may be approved on a case-by-case basis. Commutating capacitors shall be a paper or plastic film type and incorporate a nontoxic impregnant, and shall be chosen to give a service life of at least 20 years. Filter capacitors shall have high ripple rating for long life, and the sum of the DC and AC ripple voltage shall always be less than the capacitor's voltage rating at a maximum case temperature of 185 degrees F. All high voltage filter capacitors, shall make use of bleeder resistors and/or other techniques to ensure their reduction to less than 50 volts within 1 minute in the absence of car motion and externally supplied power. The methodology details and expected results shall be submitted to the Engineer for approval during Design Review. The resistors and their installation method shall be such as to ensure long life.

Except for accelerating and braking power resistors (unless determined to be necessary), all resistors shall be derated 50 percent for power dissipation. Transformers (other than the main transformer) and inductors shall be derated at least 10 percent for current, or other appropriate approved factor, based upon the duty cycle. Circuit design shall employ protective techniques such that failures in power semiconductors shall fail safe or fail open, and not cause consequent failure of components or major devices following them in the circuit. Except for the case of integrated circuits, or where environmental conditions make it a necessity, as exempted by the Engineer, no module employing multiple components shall be made nonrepairable by potting.

15.26.2 Reliability Standards

A standardized MIL-HDBK-217F reliability part stress prediction shall be performed on all electrical and electronic control systems. This reliability prediction shall be based on the "ground Mobile" environment. Use of alternative reliability database information may be permitted for parts not contained in MIL-HDBK-217F, subject to SEPTA approval. Submittal of the reliability prediction shall be identified in the Reliability Program Plan. The prediction shall be used during design and development to compare competing designs, perform design tradeoffs, detect overstressed parts and identify high failure rate items.

A documented closed-looped Failure Reporting and Corrective Action System (FRACAS) (per Reliability Toolkit: Commercial Practices Edition) shall be established and maintained to provide for the identification, tracking, and repair of all product/process failures. Early elimination of failure causes or trends shall contribute significantly to reliability growth and continuous process improvement.

All semiconductor devices shall be derated to operate within the acceptable region for electrical and temperature stress as specified in "Reliability Toolkit: Commercial Practices Edition". If there is a conflict between guidelines given elsewhere in this Specification (e.g., Section 15.27.2) and the Reliability
Toolkit, the more restrictive condition shall govern. Other service-proven devices may be submitted for approval.

All electronic assemblies shall undergo Environmental Stress Screening (ESS). The temperature cycling regimen shall be in accordance with table 7.5-2, unit column, of the Reliability Design Toolkit: Commercial Practices Edition, from the Reliability Analysis center, except as indicated below. The temperature extremes may be limited to $-13^\circ F$ to $+158^\circ F$, at the discretion of the supplier. A minimum of 20 complete temperature cycles shall be conducted. The ESS shall be performed with the equipment operational, powered, and oriented as per the ultimate application. Input signals and output loads to simulate the maximum power dissipation condition in the equipment shall be applied during the rising temperature and maximum temperature portions of the temperature cycle. The equipment shall be given a full functional test before and after the ESS, and monitored for failure throughout the ESS. In the event of equipment failure, the repaired equipment shall be given another complete ESS test. Alternatives to this baseline ESS may be acceptable at the discretion of SEPTA. Assemblies consisting exclusively of components rated at 50Amperes or greater are exempt from this requirement.

15.26.3 Ability to Repair

All electrical assemblies, where practical, including such items as PC boards, shall be designed for repair by SEPTA, in their electronics workshop.

Assemblies shall not be sealed, potted, or constructed to prohibit repair by SEPTA. Assemblies that must be potted or sealed by design shall have a minimum ten (10) year warranty.

15.26.4 Hardware

Refer to Section 15.4.2 for general hardware requirements. All hardware associated with electronic and electrical control systems shall be protected against moisture, oxidation, and common airborne contaminants. Hinges and latches shall be of stainless steel.

15.26.5 Enclosures/Racks

All circuit boards that are rack-mounted shall plug into racks containing the mating half of the circuit board connector. The circuit board rack shall mount in an enclosure conforming to requirements in this document. The rack, circuit board, and circuit board hardware shall be designed as an integrated system.

The rack and enclosure shall provide environmental and EMI shielding as required to meet the requirements of this document.

Printed circuit boards shall be positively retained by means of keeper bars or other approved method. The enclosure or rack cover shall not be used to retain the circuit boards, unless specifically designed to do so.

Each circuit board shall be fitted with an ejector or hand grip to assist in board removal. The rack and the edge of each board, or the card ejector, shall be labeled with corresponding numbers to identify board location within the enclosure. A brief functional designation shall also be included on each label.
The enclosure/rack shall not be connected to the power supply return or signal circuit, unless approved by SEPTA.

Where it is necessary to use printed circuit boards that are not plug-in and not mounted in an enclosure, the following additional requirements apply:

- The PC board must be protected from mechanical damage and hostile environments such as arc discharge or contact with high voltage.

- If the PC board is part of a high voltage circuit, special caution shall be used in its design with regard to strike distance and creepage in the transit vehicle environment. This includes between PC board components and with respect to any grounded mounting surfaces.

- Any test points required in routine testing or fault isolation to the user replaceable level shall be easily accessible with no disassembly or tools.

- If replacement of the PC board is required (as part of secondary maintenance), no special tools or soldering shall be required.

Each PC board use and application of this type is subject to SEPTA approval.

15.26.6 Optical Fibers

Any application of optical fibers shall be approved prior to implementation. This approval is not intended to discourage the use of optical fibers. Rather, it is to verify reliability and maintainability of the proposed application. In no case shall the on-car repair of an optical fiber require sophisticated or complex polishing and alignment. The connections between optical fibers and car-replaceable units shall be via approved "quick disconnects".

15.27 SEMICONDUCTOR STANDARDS

15.27.1 General

Semiconductors shall be selected to withstand all continuous and transient voltage and power demands present in the circuit application without damage or reduction in life. All circuit designs shall provide for the presence of high current switching equipment on the vehicle and the resultant induced voltages and currents in electrical equipment.

15.27.2 Ratings

Semiconductors, except diodes (see below), operated from the battery supply, or those connected to trainlines, shall have minimum breakdown ratings of four times the maximum achievable circuit voltage. Suppression devices shall be provided as necessary to protect the devices and limit the circuit voltage.
Diodes operated from the battery supply, used as suppression devices, or connected to trainlines shall have a minimum breakdown rating (PIV) of 1,000 Volt. Diodes with less than 1,000 Volt PIV rating may be used if adequate circuit transient protection is also provided.

All discrete semiconductors operated from inverters or other isolating devices shall have a minimum breakdown rating of two times the maximum circuit voltage, except where specifically detailed otherwise. Suppression devices shall be provided as necessary to protect the devices and limit the circuit voltage.

All semiconductor junction temperatures shall be limited to 257°F (or to the maximum rated temperature for the device, whichever is less) or less at maximum ambient temperature and at maximum rated output power.

All semiconductors shall be operated at less than 50 percent of the maximum continuous current rating or 50 percent of the maximum continuous power rating, whichever is more restrictive. High power/current devices may be exempt from this requirement with prior approval, on a case-by-case basis. The Contractor shall submit complete device information, including all manufacturer's application recommendations, and calculated current and power demands with all waiver requests. If approved, such waivers do not reduce other requirements, including reliability.

Integrated circuits operated from the battery supply through inverters or other isolating devices shall be operated within the voltage and current ratings specified by the manufacturer, de-rated to less than 50 percent of the maximum stress level at the maximum operating temperature of the device as specified by the manufacturer.

Where the supplies to integrated circuits are regulated and surge protected, the voltage rating shall be 15 percent below the manufacturer's recommended maximum. In addition, the maximum power shall be limited to 50 percent of the manufacturer's specified maximum at the maximum operating temperature.

Silicon semiconductors shall be rated for operation over the temperature range of -40°F to 185°F, and shall be hermetically sealed to the extent required by the application.

All Gallium Arsenide and similar optical semi-conductors shall be rated for operation over the temperature range of -40°F to 185°F.

### 15.27.3 Component Burn In

All plastic semiconductors shall be burned in and screened for defects to a level equivalent to MIL-STD-883, Method 5004, Reliability Class B, or approved equivalent. The method used SV 16.0 16 - 32 Conformed Version – April 2009 must be submitted to the Engineer for approval. As a minimum, the supplier shall have had a proven effective component screening and burn-in program in effect for 5 or more years. Alternative methods based on a minimum 100 hour burn-in for the completed device which uses the semiconductors will be considered. The burn-in must be performed with the equipment operational (power on) and with the necessary input signals and loads to simulate the maximum power dissipating condition in the device at the maximum ambient temperature. Hermetic semiconductors shall receive screening and burn-in to procedures that can be documented to have produced assembled product reliability in accordance with the overall system requirements in this specification.
15.27.4 Availability and Identification

All semiconductors shall be available from at least two manufacturers and available from U.S. distributors. Single source devices, such as high voltage power devices, microprocessors, ASICs, and related support chips may be used only if approved by SEPTA. Such devices shall be essential to the proposed equipment, shall meet the proven service requirements, and shall be supplied by veteran manufacturers likely to support the device.

Each device shall be labeled to identify both the manufacturer and the complete part number. Operational characteristics of the device shall be published and available to SEPTA.

15.27.5 Other Prohibitions

Electronic equipment shall utilize stock components and shall function properly with the component manufacture’s full range of tolerances such that after-purchase screening or testing of components shall not be required.

Matching of components is permitted only if the components are normally available from the manufacturer in matched sets.

Germanium semiconductors shall not be used.

15.28 PRINTED CIRCUIT BOARD STANDARDS

15.28.1 General

Printed circuit boards shall be designed, constructed and inspected to EN standards and/or ANSI/IPC-D-275, latest revision, except where more stringent requirements are noted here. Within ANSI/IPC-D-275, printed circuit board classes are designated. Printed circuit boards supplied under this Specification shall be Class 2, minimum, with the exception of wayside computers that are not utilized in vehicle operation. Class 3 requirements shall apply to all vital equipment.

Circuit board material shall be per NEMA Standard LI 1, Type FR-4 (MIL-P-13949, Type GF), for boards which have no components whose power dissipation is greater than 2 Watts and when said board is not mounted adjacent to components dissipating greater than two watts. Otherwise, circuit board material shall be per NEMA Standard LI 1, Type FR-5 (MIL-P-13949, Type GH).

Printed circuit boards shall have a minimum thickness of 0.0625 inch base material. All conductor material shall be copper and shall be firmly attached to the board and shall be resistant to blistering and peeling when heated with a soldering iron.

All printed circuit boards shall be designed for ease of testability per ANSI/IPS-D-275, "Testability design check list".
Traces shall be made as wide as practical, with the minimum width being based on a 18°F temperature rise.

Components with pins shall be mounted only on one side. Connections shall be made to the other side or internal layers via plated through holes. SMT devices may be mounted on both sides if part of an approved existing design.

All circuit boards shall be inherently stiff or shall be reinforced to prevent damage due to vibration or handling. Circuit boards larger than 100 square inches shall be centrally stiffened unless otherwise approved.

All printed circuit boards with the same function shall be interchangeable between equipment groups without additional adjustment.

All printed circuit boards shall be of the "plug-in" type, with positive support against vibration. Single board applications, where approved by SEPTA, may be of a "non-plug-in" type.

Printed circuit boards shall be designed for insertion and removal with power applied, except where power is removed by a switch adjacent to the card rack and except where the mechanical construction would generally prohibit removal and insertion with power applied. Where a switch is used, it shall be labeled with a warning regarding its proper use.

15.28.2 Marking
All circuit boards shall be labeled with a part number, serial number, and descriptive nomenclature.

All components shall be labeled on the board with component drawing references and such other information as may be required to repair and troubleshoot the board, except as approved by SEPTA. The component and wiring sides of the board shall each be marked to indicate capacitor and diode polarity, and at least two leads or one lead and a graphic symbol indicating orientation of all transistors and thyristors.

Integrated circuits and other multi-terminal devices shall have an index mark on the component side of the board, visible with the component inserted, to indicate proper keying and insertion; additionally the first pin on all IC packages shall be identified on the wiring side of the board. The labels used to identify components on the printed circuit board shall match those used in the schematic drawings for that particular component.

15.28.3 Component Mounting
Components shall be fastened to the board in such a manner as to withstand repeated exposure to shock and vibration. Large components shall be supported in addition to the solder connections. Power resistors shall be mounted on standoffs so that the resistor bodies do not contact the board, spaced far enough away from the board so that resistor produced heat shall not discolor or damage the board.
15.28.4 IC and Device Sockets

IC and device sockets are prohibited except for components that must be removed for reprogramming or initial calibration procedures or devices that are available only in mounting in sockets. All socket applications are subject to SEPTA approval. All other components shall be soldered in place.

Where approved, IC sockets shall comply with approved standards such as MIL-S-83502 and MIL-S-83734, as is applicable for the device, and shall be made of the following materials:

The bodies shall be molded from diallyl phthalate, PTFE Teflon, or approved equal.

The contacts shall be fabricated from beryllium copper and shall be plated with a minimum of 0.000030 inch of gold over a minimum of 0.000050 inch of low stress nickel in the area of contact with IC pins.

15.28.5 Conformal Coating

Both sides of the assembled printed circuit boards shall be coated with a clear insulating and protective coating material conforming to MIL-I-46058 latest revision, or approved equal.

The Contractor as part of the recommended spares submittal, shall include a list of recommended printed circuit boards which shall remain available for the life of the locomotive.

15.28.6 Keying

All printed-circuit boards shall be mechanically "keyed" to prevent insertion into the wrong slot or in the wrong orientation. Further, circuit boards in safety related control systems, such as friction brakes, cab signal, ATC, ATS, and systems which can cause damage or unsafe train operation if the vehicle is operated with a card removed, shall be connected through a safety circuit to disable the vehicle if a circuit board is removed.

15.28.7 Circuit Board Connectors

Printed circuit board connectors shall be heavy duty, high reliability, two-part type with a history of successful service in rail applications and shall be approved by SEPTA prior to commencing design.

Connectors which comply with MIL-C-55302 or DIN 41612 Level 1 or 2, and which have plated contacts as described below, are considered to comply with the requirements of this section.

The connector contact area shall be plated with a minimum of 0.000030 inch f gold over a minimum of 0.000050 inch of low stress nickel.

Card edge connectors are prohibited.

15.28.8 Testing

Sufficient clearance shall be provided between components to allow testing, removal, and replacement without difficulty due to lack of space.
Test points shall be provided in appropriate locations on modules and printed circuit boards. A negative return test point shall also be provided. The test points for manual testing shall either accept and hold a standard 0.080 inch diameter tip plug or shall be a turret lug similar to Cambion No. 160-1026-01-05, or approved equal, with sufficient clearance to permit it to accept a standard oscilloscope probe clip, and shall be identified by appropriate markings.

15.28.9 Extenders

Printed circuit board extenders shall be provided by the Contractor for test purposes. At least two extenders of each type shall be available for use and evaluation throughout the design conformance and acceptance test programs and shall be delivered to SEPTA upon the acceptance of the BTE. The interfaces between extender and enclosure and PC board must be positive and secure and must prevent malfunction and falling out during testing. Mechanical locking means shall be considered on large PC boards.

15.29 INTERFERENCE AND TRANSIENT SUPPRESSION

All electrical devices and wiring shall be carefully planned and selected to avoid electrical interference in the operation of the propulsion and braking system, train radio, public address and any other frequency sensitive systems. This shall include the use of shielded cables, chokes, filters, and capacitors, as required by good design standards, to avoid possible interference with these systems. Adequate voltage transient suppression shall be provided for the protection of panels and circuitry involving semiconductor devices. Low voltage circuits shall be capable of withstanding 1.5 joules, unless otherwise approved by the Engineer.

Apparatus creating EMI emissions shall be designed to contain these emissions within their package area. Suppressors shall be incorporated across inductive devices to minimize switching transients. All suppression devices shall be selected on the basis of their ability to absorb the amount of energy available in the connected circuit, for the number of cycles of operation expected in service, without requiring replacement prior to scheduled overhaul. All magnet valves and relay/contactor coils shall have free-wheeling diode or metal-oxide varistor voltage spike suppression, or other suppression means, except where this results in deterioration of performance. Coil suppression devices shall be located physically on or as close as possible to the coil it protects (preferably directly at the coil terminal). Wherever possible, the suppression of transients shall be at the source.

15.30 SOFTWARE AND SYSTEMS

15.30.1 General

This section includes requirements at the systems level as well as the software and related hardware levels. The systems level includes the overall car level and the individual systems level.

All software and related electronic hardware for this project shall be subject to the requirements of this Section. This includes, but is not limited to, software systems for control, monitoring, diagnostics, portable or bench test equipment, and wayside data analysis. No exception is made for items that may...
be considered firmware. Systems that include data files or configurable or customizable components such as Field Programmable Gate Arrays (FPGAs) are also covered by sections below.

The specific application requirements for the individual systems are given in the corresponding sections of this Specification while the common requirements, pertaining to all such software systems, are given in this section. The additional requirements given here include both design requirements and documentation requirements.

The major goals for this section are to assure that these software systems are complete, reliable, require few if any changes late in the development cycle, are provided on schedule, and are changeable in the future without compromising design integrity. To achieve these goals, plans are needed early in the project; the requirements for software must be analyzed; and designs developed that meet all the requirements.

Documents shall need to be read by numerous people during development and in the future for problem analysis and changes. It is important therefore, that all documentation be easily and unambiguously readable.

The Sections below require first, that the overall functions and design structure of the locomotive systems be described along with the internal breakdown of the systems into software and hardware components.

Later sections below give requirements for the software and hardware components, as well as for how they shall be documented.

The software must be treated as an integral part of the total system design and shall be reviewed as part of each design review for the corresponding systems.

## 15.31 Systems Requirements

### 15.31.1 General

The Contractor shall be responsible for the overall design and for the integration of the systems into the complete system. Each subsystem is then designed and documented by the supplier with the Contractor reviewing the designs and testing the completed systems.

### 15.31.2 System Documentation

1. Contractor’s Overall SFD
   The Contractor shall provide an Overall System Functional Description (Overall SFD) that shall define hardware and software components, the partitioning of the system functions, and the allocation of requirements (including derived requirements) to the individual Systems.
The Overall SFD shall include a diagram of the complete system to be provided. It shall show the systems with their interfaces including network interfaces. The terminology of the overall SFD document must be consistent with that of this Technical Specification. The locations of systems within the locomotive shall also be shown in diagrams and described.

The allocation of requirements to multiple systems shall be clearly described with attention to derived requirements such as the allocation of timing requirements that together provide an overall timing requirement.

The SFD shall define any commonalities between the systems such as networking standards or other shared interfaces. Interface Control Documents (ICDs) shall be used to document all significant interfaces between systems. The ICDs shall conform to IEEE Standard 1558-2004.

2. Individual Systems SFD Required Content
For each individual System, the Supplier shall provide a System Functional Description (SFD) that completely describes the system and how it meets the project requirements. These SFD documents shall be consistent with the overall SFD and with this Technical Specification.

The SFDs shall provide the following:

- A Context Diagram showing the system and the external interfaces. There shall be an accompanying description of the functions of the system and the relationships of the system with other systems.

- A Decomposition Diagram and Description shall describe all System Components and internal interfaces.

- Each hardware component shall be described to the level of its major components, LRUs, LLRUs, the functions to be performed, and the interfaces.

- The components shall be further broken down to the Hardware Components, Software Configuration Items, the internal interfaces within the system, and the external interfaces to other car level systems.

- Each Software Configuration Item (SCI) shall be described in its own numbered section. The major functions of the item shall be described and the relationship to the hardware including memory and input/output hardware. The power fail shutdown strategy shall also be described.

- A Software Summary Table with a row for each software item in the system, including proposed Commercially Available (CA) items. Columns shall give the Software Configuration Item name and ID, Software Requirements Specification (SRS) name and ID, Software Design Description (SDD) name and ID, and section within the SFD where the SCI is described. The use of the proposed CA items and their classification as CA for the purposes of this project shall require approval.
• The descriptions of hardware items shall also include explanations of how the hardware requirements of the Technical Specification shall be met.

• For Programmable Components such as FPGAs, Complex Programmable Logic Devices (CPLDs) and other similar devices, all specific hardware and programmed functions and the interfaces shall be defined in a dedicated section. This description must include the requirements to be met by the item. The detail design for those items shall then be documented separately in the schematics or in an appropriate application file and output file of the software tool used to program the device. If data files are to be separate configuration items, their content must be described also.

A Failure Detection and Remedial Action description section shall describe monitoring the correct operation of system components, the failures to be detected and the remedial actions for minimizing the impact of the failure. Failure detection should facilitate root cause analysis, and repair. The description shall include the detection of sensor input failures and compensation schemes such as the use of alternate sensors or performance restrictions.

15.31.2.1 Testability

All features and functions of software systems shall be testable on a systems level. Specific approval is required for any feature that is not testable on a systems level. For features that are only testable with special equipment, all such equipment shall be supplied by the Contractor as special test equipment and become the property of SEPTA. This equipment shall provide the logic, sequencing, and emulation necessary to verify that the software functions as intended. In lieu of separate equipment, appropriate test functions may be provided within the Portable Test Equipment (PTE).

Type tests of all processor systems shall verify the proper operation of all software features, including component failure detection and diagnostics.

All Test Plans and Procedures shall be submitted for approval prior to conducting the tests. Each requirement of the SRS must be traceable to the test procedures using the Software Requirements Traceability Matrix.

15.31.3 Software

15.31.3.1 General

The requirements of this section pertain to all subcontractors providing software (including Programmable Devices). If the Contractor shall supply software for this project then they shall also be considered a Supplier and shall also be subject to the requirements of this section pertaining to suppliers.
15.31.3.2 Contractor and Supplier Qualifications

The Contractor, as systems and software integrator, and suppliers who are providing processor-based products shall have a mature software development process. To confirm its capability, the Contractor shall submit an independent Software Capability Evaluation (SCE) for themselves and for each supplier. Even if the Contractor shall not directly produce software, the overall software design, integration, and subcontract management are critical to the success of the project. Consequently, the Contractor's SCE is still required. In each case the SCE must cover the entire range of activities, by the Contractor/Supplier, relevant to the project.

The independent evaluations shall include the use of a lead assessor who is certified by the Software Engineering Institute (SEI) and shall be conducted according to the methodologies established by the SEI. A ranking in accordance with the Capabilities Measurement Model (CMM) shall be developed for the Contractor and each supplier of software. Previous rankings from calendar year 1999 or 2000 may be used without a new evaluation. The Contractor's evaluation report and each supplier's report must be provided to SEPTA for approval 120 days after NTP and concurrent with the submittal of the quality assurance manual per Section 19.10.4.

If the Contractor's ranking is below CMM level 2, and for each supplier with a ranking below CMM level 2, a course of action must be defined to mitigate the impact of the problem areas on the project and to improve the processes to at least a CMM level 2. To this end the Contractor or supplier shall submit for review and approval the following along with the SCE report described above:

- An impact report describing how each of the problem areas identified in the SCE report would impact the project.

- A remedial action plan defining the activities, resources, and schedule the supplier shall commit to for improving their operation and achieving a level 2 or greater CMM rating on a subsequent evaluation. The plan shall be based on the SCE findings and shall prioritize the efforts to maximize the benefits to the project. The plan must include the completion of all required activities and successful reevaluation at CMM level 2 or higher before the contract closeout.

- A project specific interim plan. For problem areas where the above remedial action plan cannot result in permanent process improvements in time to affect the project, specific procedures, reviews, reports, or other activities for the project shall be defined to compensate in these problem areas.

The contractor shall submit monthly progress reports identifying progress to plan on the above and any changes to the plans. The reports must demonstrate a concerted effort and tangible results. Reports shall continue up through the submittal of the final SCE report confirming a level 2 rating.

15.31.3.3 Software General Features

Software shall perform the following basic functions:

Implement the desired control scheme or other functions such that the specified performance is achieved;
Monitor all inputs for unsafe, erroneous, or unknown conditions or combinations of conditions and take appropriate actions to preserve proper functioning and capture appropriate information to facilitate root cause analysis and repair.

- Sample all input conditions and hardware status at rates sufficient to detect and remedy all unsafe or damaging conditions in the shortest possible time. Sampling rates and program execution times shall be such that the control system is not the limiting factor in response to unsafe or damaging conditions. All software shall be designed to ensure that the timing requirements for safety-related tasks are always met;

- Limit all output commands to safe levels regardless of any combination of input conditions;

- Perform self-diagnostic routines and respond promptly, safely, and predictably to detect faults. The self-diagnostics shall include tests for program corruption and for integrity in read/write memories;

- Respond safely and predictably when powering up or recovering from power interruptions. All power interruptions likely to have corrupted temporary storage shall be detected and cause the system to re-initialize all affected routines and temporary data. Detection of power interruptions may be by hardware; and

Permit thorough interrogation of all input, output and internal conditions by external diagnostic equipment.

Software shall be designed to minimize the interaction between functions and reduce the coupling such that changes in one area are unlikely to affect other functions.

Programs shall be modular with separation of Operating/Executive Software from Application Software. Software version numbers shall be included within the code. Programs stored in sets of memory devices must self-test to assure that the correct complement of devices is installed. Software shall have verifiable version control based on a Cyclic Redundancy Check (CRC-32) polynomial published in the software documentation and verifiable using an approved utility. This utility shall be included in the Portable Test Units (PTUs), Software Workstations, and the Monitoring and Diagnostic System (MDS). When requested by these systems, the software shall calculate the CRC-32 value and report it along with the version ID. The CRC-32 value shall be provided with each release of a Software Item.

Processor system parameters shall be adjustable via PTE. Appropriate parameters shall be suggested by suppliers during design review for approval. User defined/changeable parameters shall be structured as tabled data. Allowable ranges of parameters shall be stated in the SRSs as requirements and the software shall restrict setting of parameters to these ranges.

In the event that vital functions are performed in processor based systems, functionality shall be verified in accordance with IEEE STD 1483-2000, “IEEE Standard for the Verification of Vital Functions in Processor-Based Systems Used in Rail Transit Control”.

15.31.3.4 Software Activities

The Contractor and Suppliers must plan the activities they intend to perform in order to provide the required software and related documentation. These plans must be documented and submitted to SEPTA so agreement can be reached regarding them. Plans must include schedule and resource allocations sufficient to meet the submittal requirements of the Technical Specification. Progress shall then be monitored according to the plan to assure on-time delivery and assure the software meets all requirements.

Software Requirements Analysis must be performed for each Software Configuration Item to determine all requirements from all sources. These requirements must be documented in a SRS and submitted for review. The requirements analysis must be performed early in the process to allow for general review and to allow the design to be developed considering all requirements. A Software Test Plan shall also be developed at the time of requirements documentation.

Software Design shall include software design activities and documenting the design.

The reuse of software from previous applications is encouraged, as long as the full set of requirements in this Contract are addressed. This includes both functional requirements and requirements of this Section such as those for language, structure, maintainability and error detection. Requirements analysis, design, and the documentation of both are needed regardless of the intended re-use of the software items.

Suppliers must conduct formal reviews for each document with review minutes submitted along with the documents.

15.31.3.5 Software Documentation

1. General

Software documentation shall be in accordance with IEEE Standard P1558-2004, “Standard for Software Documentation for Rail Equipment and Systems” and with the additional requirements set forth within this document. The IEEE 1558 requirements shall be for a type 5 system as defined within that standard.

Some software items may be classified by SEPTA as Commercially Available (CA) for this project. Requirements for these items are given in the Technical Specification.

SEPTA shall be provided with sufficient documentation to fully comprehend and analyze the operation of the equipment in which the software is to be installed. The documentation shall describe how all requirements shall be met. Software documentation training shall be included within the formal Training Program. Submissions shall also conform to the requirements of the procurement contract documents.

2. Application Software

All documents shall be in a common format within the set of Contractor documents and within each of the sets of documents from each Supplier. These formats shall use a
consistent set of graphical and textual techniques to fully describe the software functionality and implementation.

3. Contractor Requirements
The Contractor shall develop and submit for approval a Software Project Management Plan (SPMP), a Software Quality Assurance Plan (SQAP), a Software Configuration Management Plan (SCMP), and a Software Verification and Validation Plan (SVVP), all in accordance with IEEE Standard 1558-2004. The scope of these documents shall cover the entire software development for the project. These documents shall be submitted for approval soon after the NTP, before the submittal of other documents. The Contractor Software Verification and Validation Plan (SVVP) shall describe the integration of the subsystems to cover the requirements of the entire system.

An SVVR is also required with each Software release presenting the Contractor V&V activities.

4. Supplier Requirements
Each Supplier shall create and submit the full set of documents conforming to IEEE Standard 1558-2004 Standard for Software Documentation for Rail Equipment and Systems for type 5 as defined in that standard.

All documentation shall use names and acronyms consistent with those in the Technical Specification and as defined in the Contractor Overall SFD and the SFD for the specific system.

The problem reporting and corrective action process shall provide reports allowing the easy tracing of problems found at each development stage back to changes in the requirements, design or implementation in source code.

Each software release shall be provided in a package including a consistent set of up to date and approved software documents, test reports, the updated SVVR, and a Software Version Description (SVD).

All references to documents shall specify the location to a sufficiently specific section of text so the reader can easily and unambiguously understand the intention.

All source code, including comments, shall be in English. Source code must be well structured, modular, and clearly documented to allow easy comprehension and straightforward traceability to the SDD documents. Software comments shall also include explanation of all significant memory addresses such as interrupt vectors, I/O addresses, and memory locations for RAM, ROM, and other memory devices. Files and modules must have headers describing functions, interfaces and change histories. Proposals for escrow agreements shall be considered according to the Terms and Conditions of the Contract.

All documents shall be submitted as separate documents, not as internal to other submittals such as the PDR, In-Progress Design Review (IPDR), or CDR documents. All documents shall use names and acronyms consistent with those in the Technical Specification and as defined in the Contractor overall SFD and in the individual system SFDs.
The Contractor shall assure that the documentation produced provides for the straightforward traceability of requirements of the Technical Specification throughout the design documentation and final test. This shall include derived requirements as well.

5. Additional Requirements for Software Documents

A. Software Project Management Plan (SPMP)
   Details shall be provided describing monitoring of Supplier activities to assure development tasks are completed and delivery requirements are met for each development phase from concept development to warranty support. It shall describe the procedures used to conduct software quality audits for suppliers and subcontractors.

   The Software Project Management Plan (SPMP) for both the Contractor and the suppliers shall include a schedule showing the key tasks defined for the software development. A Gantt chart shall be used showing the timing and interrelationships between tasks. This schedule shall include the allocation of time and resources for realistically addressing issues raised by internal reviews, Contractor reviews, or by the Authority. The SPMP shall include detailed descriptions of the metrics to be used to monitor and control the project. This shall include monitoring project progress on intermediate tasks and triggering management corrective actions with sufficient time to assure required deliveries are met.

B. Software Verification and Validation Plan (SVVP)
   The supplier’s Software Verification and Validation Plan (SVVP) shall require internal peer reviews of each version of the documents and source code. Summary reports of these reviews shall be included in the Software Verification and Validation Report (SVVR). For each review it shall also state the version of the items reviewed as well as the versions of all related documents used in the review. These include, for example, documents that the subject item was reviewed against such as an SRS or related interface specifications used in the review of an SDD. The review reports shall list for each V&V task, the type of review, the participants, the date, the versions of all items used in the review, and all issues from the review. The SVVP shall also require reviews of each design or source code change prior to test and release. Summaries of these also are required in the SVVR.

   Similarly, test reports summaries shall be included in the SVVR and they shall identify the version of the SCI tested, the test plans, and the versions of all additional items used in the test.

C. Software Requirements Traceability Matrix (SRTM)
   The Software Requirements Traceability Matrix (SRTM) shall provide cross-referencing between the requirements of the SRSs and the corresponding sections of the SFD, SDD/ICD/DBDD, and the Software Verification Test Procedures. It shall include one table for each SCI and within each table there shall be a row for each SRS requirement. The columns shall include the unique identifier for the individual requirements defined in
the SRS, a short description of the requirement, the reference to the corresponding SFD section, the reference to the SRS section, the reference to the SDD section or sections, and the reference or references to the Software Validation tests. Since the references are dependent on the version of the documents referenced, the specific versions of all referenced documents must be stated for each table.

All references to documents shall specify the location of the pertinent text to a sufficiently specific section so the reader easily and unambiguously understands the intention.

D. Software Version Description

SVDs shall be provided with each version of the software items. Each SVD shall include a description of the problems addressed or features added, changes to software requirements, changes to the software design, a record of review results for each pertinent document, test plan changes, and test results. The SVD shall be submitted to SEPTA before use of the software in official tests or on the locomotives.

15.31.3.6 Escrow Account

The placing of software design documentation details, such as proprietary source code or compilers, in a third-party escrow account, in lieu of submittal to SEPTA, may be permitted, subject to Engineer approval, provided that sufficient software information is provided (submitted and/or shown to an approved reviewer) to enable the Engineer to evaluate overall system performance. The Contractor shall conduct a software escrow verification test for all escrowed software. These tests, at a minimum, shall verify that all software and developmental tools have been escrowed to compile, link, or otherwise generate the firmware, object code, P- Code, executable code, or whatever is required to run on the vehicle system or portable test equipment or other software-based system supplied by the Contractor or its subcontractors. The escrowed software design, documentation details, source code, etc., shall be made available to SEPTA for its own use if the Contractor or its subsupplier is no longer in business, or no longer supports the product and has not transferred the rights to the design to another entity, or if, based on an independent third party assessment, the Contractor or its subsupplier no longer supports the product at a reasonable cost. SEPTA shall be granted a no-cost license to use and maintain all software required to operate or maintain the cars for the car lifetime.

15.31.3.7 Operating Systems and Languages

Software may be written in a high or low level language although high level languages are preferred. The language, and its implementation for the selected microprocessor system, shall be commercially available in English. No proprietary languages or code generating systems shall be allowed. All languages and operating systems must have an acceptable installed base and be approved. Languages shall be described in the Methods, Tools, and Techniques sub-clause of the Suppliers SPMP.

15.31.4 General Market Software

Some software supplied under this procurement may be purchased by the suppliers from external sources and commercially available to a wide variety of users. Examples include operating systems and data base software for fault analysis. The Contractor shall submit for approval a list of software that is
commercially available to the general public and which the Contractor and supplier would like to be considered Commercially Available (CA) for this project. This category does not include supplier software.

For Commercially Available software, software documentation requirements are limited to: the original data storage/transfer media (CD-ROM or diskette), functional and usage details, all provider manuals, and licenses required for SEPTA site use for all hardware provided under this Contract. The requirements and interfaces shall be documented in a specific section of the SFD for that component of the system. References to specific sections of the provider's documentation shall be included for all requirements. The Contractor shall incorporate training on how the software is to be used in the specific situation for which it was provided as part of the Training Program.

15.31.5 Time and Date Processing

All systems provided under this procurement, whether acting separately or in combination, must properly process all times and dates within the required span of years from 2000 to 2100 inclusive. This includes all car-borne software as well as all PTUs, Development Systems, Operating Systems, and workstations.

The Contractor and suppliers shall be required to provide robust designs and to establish, through both analysis and test, that the product shall process times and dates correctly. An example of a design that may not correctly process dates throughout the required range is storing time as seconds past 1-1-1970. This technique must either not be used or, if used, must be extended to correctly process all required times and dates. Requirements for proper time and date processing must be included in the SRSs for all systems for subsystems that use times and dates.

Since setting the time and date is required as part of the normal operating of the locomotives and is required for system validation testing, the design must allow for setting of the time for the whole system or for any part of the system, forward or back, to any time in the required span of years, without incorrect operation or loss of data.

15.31.6 Hardware

15.31.6.1 Hardware Platform

Microprocessor-based systems shall be based on an established family of microprocessors in wide use in the control system industry. They shall be supported by a full range of software development languages and diagnostic programs. Any use of commercially-available computer boards must be specifically approved. Such approval shall be based upon a technical review of the product, product documentation, and a commercial assessment of product availability.

15.31.6.2 Electrical Isolation and Pre-processing

The control system shall be powered by dedicated transformer-isolated power supplies driven from the low voltage distribution network.
All control system input and output signals shall be through isolation buffers. High voltage inputs and outputs shall be isolated external to the microcomputer card rack. Low voltage (battery and logic voltage level) inputs and outputs shall be isolated via buffer cards in or external to the microcomputer card rack. The isolation buffers shall:

- Protect and isolate the control system from damage due to over-voltage, under-voltage, transient, shorts and opens;
- Perform necessary voltage translations;
- Remove noise and undesired signals;
- Limit, pre-process, discriminate and format those signals that would otherwise require excessive processor time; and
- Consist of optical isolators, transformers isolators, and other circuits appropriate to the application. Voltage divider circuits shall not be allowed.

15.31.6.3 Program and Data Storage

Program code and fixed data shall be stored in a form of PROM. All EPROM windows shall be covered with labels that are opaque at the Ultraviolet (UV) erasing wavelengths. Flash PROM circuitry shall be configured so that reprogramming can be disabled via a semi-permanent hardware mechanism. After the software design has stabilized in revenue service, flash PROM reprogramming shall be disabled. The approved hardware key shall be a small electronic device that attaches to a parallel port or other similar interface on the laptop Personal Computer (PC) used for the PTE. The laptop PC shall interact with the hardware key so as to allow loading of software to the locomotive subsystem only if the hardware device is attached. If a system does not disable flash PROM reprogramming in the equipment itself, then it is acceptable to use a PTE where both a password and an approved hardware key are necessary for the PTE to download software. The same hard key shall be used for all systems. One hard key shall be provided for each PTE. The device shall be designed such that duplicate units may not be unofficially obtained. The device shall be programmable by SEPTA to limit its use (e.g., contains a time limit, only works with a specific PTE, etc.)

15.31.6.4 Batteries

Rechargeable batteries shall be sized to retain data for at least six (6) months without charging and shall be located such that leakage cannot damage any control system components. Battery life shall be no less than five years, regardless of type. The system shall annunciate the need for battery replacement such that the battery continues to perform its function until it can be replaced at the next periodic maintenance. Batteries shall not be connected by soldering. Non-rechargeable batteries shall be replaced within six (6) months prior to locomotive acceptance. Upon detection of the loss of input power to non-battery backed systems, the processor system shall store all necessary RAM control data to non-volatile memory. The Contractor shall provide a list of all components that include a battery.
15.31.6.5 Expansion Capacity

The hardware shall be designed to allow program expansion without hardware modification. The memory needs of the installed software shall not utilize more than 70 percent of the installed memory. This requirement applies individually to each type of memory installed, whether it is EPROM, EEPROM, Flash PROM, RAM, or other type. Peak processing time demands shall not be greater than 50 percent of the available processor time, except as indicated below. The Contractor may petition for relief from the 50 percent requirement, based on product maturity and the lack of potential for expansion or modification. In no case may more than 75 percent of the peak processor time be utilized, and generally, more margin shall be required. The hardware shall include spare input and output channels of each type used within the system, except for major output drivers, the quantity of which is fixed by the overall system design (e.g., traction motor semi-conductors and sign character drivers). In addition, the architecture and assembly construction shall allow for the installation of additional I/O hardware. Simple singular functions performed by dedicated embedded processors may utilize up to 75 percent of the available processor time and do not have to provide spare I/O capability.

15.31.7 Deliverables and Schedule

All documents submitted shall utilize revision bars in the margin and/or underline/strike through to highlight changes from one revision to the next. A change history shall be included in each document describing each change and giving the reason for the change.

The correspondence between design reviews and software submittals shall be as shown below. Issues with documents must be resolved and documents approved to close each design phase.

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Preliminary Software Configuration Management Plan (SCMP)
for Contractor and Suppliers

Preliminary Software Requirements Specification (SRSs) and ICDs

Preliminary Software Test Plans (STPs)
Preliminary Software Design Descriptions (SDDs) and Preliminary Database Design Descriptions (DBDDs) if needed at the Architecture Design level.

Preliminary Software Verification and Validation Plan (SVVP) for Contractor and Suppliers

Preliminary Software Requirements Traceability Matrix (SRTM) for each system

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Software Design Descriptions (SDDs) – Architecture Design and Detailed Design and Database Design Descriptions (DBDDs) if needed

Source Code Files

Updated Software Configuration Management Plan (SCMP) for Contractor and Suppliers
Updated Software Verification and Validation Plan (SVVP) for Contractor and Suppliers
Software Requirements Traceability Matrix (SRTM) for each system

Revisions to other documents for changes or updates

After original approval, changes to the software shall be formally submitted for approval prior to implementation of the changes in the source code. New versions of software must be accompanied by revised, reviewed and released software documentation, as well as SVVRs.

15.31.8 Configuration Control

The Contractor shall develop and maintain a Software Configuration Control Plan (SCCP) for tracking software changes relative to locomotives, PTEs, and Bench Test Equipment (BTE). The Contractor shall include in the plan a data base management system capable of maintaining the history of all software and status changes making it possible to determine which versions currently resides in which equipment, on which locomotives, and also which versions were used in the past. The data base management system shall be capable of generating various reports showing the configuration of a typical vehicle system in terms of software history and status, and also a fleet configuration report capable of determining the exact software configuration of a particular operating train on a locomotive-by-locomotive basis. The Contractor shall make these reports available to SEPTA.

The SCCP shall be submitted for approval.

The Contractor shall submit a final software configuration for each locomotive at the time of acceptance or conditional acceptance in an electronic format as approved

All software shall be identified by a name and a version number. The name shall identify the equipment into which the software is installed. Every change to software shall be reflected in an update to the version number.

15.31.9 Software Maintenance and Related Tools

The Contractor shall define and describe all items needed for software workstations including all of the software source files and software development tools used by the suppliers. The complement of equipment shall include all compilers, assemblers, linkers, in-circuit emulators, version control software,
development kits, and other such tools that are used for software development. All such software and hardware tools shall then be provided and included in the escrowed material. Development tools and software which are identified must be the version as used by the suppliers. Specific instructions for compiling and linking the specific software shall be provided. The instructions shall include software modifications and tests of all non-Commercially available software (non-CA software) on this procurement.

The instructions and software documentation is to be demonstrated, and proven to create program files that then must match the programs stored within the system’s equipment.

All associated manuals and software licenses shall be provided.

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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 slowdowns 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>
<th>Max Outward Reaction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Horizontal</td>
<td>Max Vertical Reaction plus six (6) times the TBU weight</td>
</tr>
<tr>
<td>Vertical</td>
<td>Max Vertical Reaction plus six (6) times the TBU weight</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Disc Brake Unit (DBU)</th>
<th>Max Horizontal Reaction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Horizontal</td>
<td>Max Vertical Reaction plus six (6) times the DBU weight</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>Reaction from maximum steady state torque</th>
</tr>
</thead>
<tbody>
<tr>
<td>Horizontal</td>
<td>Reaction from maximum steady state torque plus five (5) times the weight supported by the truck frame</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>

<table>
<thead>
<tr>
<th>Dampers</th>
<th>Peak force from damper at maximum operating velocity</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>Motor and Gear Unit</td>
</tr>
<tr>
<td>Dampers</td>
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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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</thead>
<tbody>
<tr>
<td><strong>Truck</strong></td>
</tr>
<tr>
<td>Vertical (Range)</td>
</tr>
<tr>
<td>Lateral (Range)</td>
</tr>
<tr>
<td>Longitudinal (Range)</td>
</tr>
<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>
</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:

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

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.

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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 all 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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</table>
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.

16.8.11.1.1 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:

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<th>Current</th>
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<td>below 90 volts</td>
<td>2 megohms</td>
<td>.00025A</td>
</tr>
<tr>
<td>1000 VDC</td>
<td>90 volts to 600 volts</td>
<td>4 megohms</td>
<td>.00025A</td>
</tr>
<tr>
<td>1000 VDC</td>
<td>above 600 volts</td>
<td>5 megohms</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>
<th>Section Reference</th>
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<tbody>
<tr>
<td>Insulation Tests</td>
<td>16.10.3</td>
</tr>
<tr>
<td>Functional Tests</td>
<td>16.10.4</td>
</tr>
</tbody>
</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.

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17 MANUALS AND TRAINING

17.1 GENERAL

The Contractor shall provide detailed education and training, plans, drawings, publications, and spare parts lists required for maintenance, repair, overhaul, testing, providing technical services, and operation of the Locomotive.

SEPTA considers the publications and related education programs which will accompany the locomotives to be of great significance a major responsibility of the Contractor. Accordingly, all publications and education program activities described in this contract shall be produced by an approved, experienced 3rd party Subcontractor with previous experience, under contract to a US industrial firm or government client, in the preparation of publications for either an electrically-propelled rail transit car procurement or a commercial/military project of equal or greater magnitude and complexity.

The Contractor shall designate in-house personnel dedicated to the organization, interface, coordination and flow of information from the originator of the equipment and the Contractor’s integration of the locomotive as a whole. The personnel shall monitor and evaluate and edit the level of completeness for each manual to assure submittals to SEPTA for review are complete in terms of being a finished, professional product. The Contractor shall facilitate any and all manual information changes associated to technical changes performed on the locomotives after the initial acceptance of both the electronic and/or published versions through the extent of the contract and warranty period of the last locomotive.

SEPTA shall have the right to duplicate and alter all manuals, training materials, equipment, simulators, and tools delivered by the Contractor.

17.2 MANUALS

17.2.1 General Requirements

Manuals shall be produced generally according to the requirements of Military Specification MIL-STD-40051-1 for electronic formats and MIL-STD-40051-2 for paper formats, as clarified by SEPTA. Material shall be in sufficient detail and form for easy use. The material in the manuals and parts catalog shall be similarly organized and sequenced with a standard numbering system.

Manual requirements for microprocessor-based systems are covered in Section 15.31.3.5.

All material used in the preparation of the manuals will be reviewed by the appropriate departments to assure that adequate information is included to satisfy the requirements of the Training Program.
Manual format throughout the documents shall be consistent from subsystem to subsystem. All vendor material shall be reworked to conform to manual format except as may be waived by SEPTA. Sharp, clear black line graphics shall be used throughout the documents for illustration. The use of color and/or photographs may be used only where explicitly approved by SEPTA, and must first pass a test of being printed in black and white via inkjet printer, laser printer and copier and found to have no loss of detail and/or identifiable properties as intended for its use as a graphic for supporting the text it is illustrating.

MIL-STD-40051-1, MIL-STD-40051-2 and MIL-M-38784 shall be used as applicable as guides in manual preparation. Chapter numbers shall be consistent for all manuals. Master art and text files shall be supplied in electronic form in accordance with MIL-STD-1840C for final delivery of manuals. Text files shall be tagged in accordance with MIL-PRF-28001C and MIL-HDBK-28001. Art files shall conform to MIL-PRF-28002C and MIL-PRF-28003B.

All manuals shall be written in a full level of detail to fully explain the working of the systems and their components as applied to the locomotive’s design. Systems shall be fully explained within the context of their integration within the locomotive in respect to interfacing any other system and/or locomotive wiring, applications or controls.

All manuals shall use a loose-leaf format. The paper shall be 100M non-reinforced 8 x 11 inch using a vertical format, except foldouts which shall be 11 x 17 inch. Diagrams shall not be loose in pockets. The binders shall be vinyl three post-hole, with clear front and spine pockets for display of printed manual designation inserts. A complete table of contents shall be given at the beginning of each manual and a complete page-numbered index at the end. Plastic coated tabs shall be used to segregate Sections within each manual.

Where applicable, the manuals shall highlight the precautions to be taken by operating, service, maintenance and/or repair personnel to ensure their safety while performing the procedures described. Such items shall be applied using ANSI Z536.6 requirements.

The topics shall be discussed to the extent necessary for a full understanding by persons unfamiliar with the vehicles or equipment, but possessing the basic skills associated with their respective trade specialties and a good knowledge of standard practices, conforming to SEPTA’s safety requirements.

Manuals required for this program are as follows:

- Operating Instruction Manual;
- Running Maintenance Manual;
- Heavy Maintenance and Repair Manual;
- Integrated Electrical Schematic Manual;
- Integrated Pneumatic Diagram (Schematic) Manual
- Illustrated Parts Manual;
• Structural Repair Procedures Manual.

17.2.2 Operating Instruction Manual

This manual shall contain all information needed by the engine crew covering the operation of the Locomotive. This shall include preparing the unit for operation and securing the unit from operation. This manual shall be collaborated with the SEPTA's Operations Division Transportation and Mechanical Departments to include full approval.

Emergency procedures and safety precautions of a specific nature shall be included. The manual shall give troubleshooting and diagnostic procedures sufficient to isolate problems which are capable of reset by engine crews, arranged in a format to allow ease of use under emergency and time-sensitive situations.

17.2.3 Running Maintenance Manual

The Running Maintenance Manual shall contain an overview of each Locomotive system, describing its operation and a detailed description and analysis of its assemblies/subassemblies. The manual shall also have in convenient form all information required for on-board testing, troubleshooting, servicing and replacement of equipment down to the lowest level replaceable item. The manual shall be divided into two volumes as listed below.

17.2.3.1 Volume I: Scheduled Inspection and Maintenance

This volume shall contain the following:

1. Detailed inspections required by the Contractor, system component suppliers and/or FRA 49 CFR statutes consisting of preventative maintenance instructions and associated testing procedures and associated forms. The inspections shall be organized by the date requirements for the event such as Daily, 92 Day, Yearly, etc.;

2. Lubrication requirements listing of all lubricants, including names of manufactures, including the frequency, location and type of lubricants for various components;

3. Removal and installation procedures for consumables and replacement items;

4. Installation and removal of equipment, in full detail, on a unit exchange basis;

5. Detailed inspection tasks and servicing information and procedures including all measuring, gauging and testing involved;

6. The weights of all components of the Locomotive and assemblies that weigh more than 50 pounds;

7. Supply and tool list;
8. Car body and truck hoisting and jacking instruction.

17.2.3.2 **Volume II: Troubleshooting**

This volume shall contain sections/chapters that contain a detailed description and analysis including the theory of operation of each subsystem, troubleshooting and corrective maintenance procedures, including but not limited to:

1. Description of the on-board monitoring and diagnostic system and instructions on its use;
2. Car Body;
3. Trucks;
4. High Voltage System;
5. Propulsion;
6. Auxiliary Power;
7. Computer System;
8. Communications;
9. Friction and Electric Brake;
10. Coupler and Draft Gear;
11. HVAC;
12. Automatic Train Control & PTC
13. A detailed description and analysis of all the portable and backshop diagnostic test equipment;
14. Locomotive system operation write-up based on the Integrated Schematic Manual, see Section 17.2.5;
15. Functional post-inspection testing and checkout;
16. Detailed troubleshooting procedures for all systems, useable with and without diagnostic test equipment.

17.2.4 **Heavy Maintenance and Repair Manual**

The heavy maintenance and repair manual shall contain a detailed description and analysis of all replaceable assemblies/subassemblies so that SEPTA's overhaul facilities can effectively and safely service, inspect, adjust, troubleshoot, repair, overhaul and test these assemblies. All systems and
associated components referenced from 1 through 12 of Section 17.2.3 shall be included within the manual set.

The Contractor and its suppliers shall provide all information needed for comprehensive repair and overhaul work to satisfy SEPTA's needs. The information provided shall be at least as comprehensive as that used by the suppliers' own service and repair shops, whether the parts were manufactured by them or purchased from others. The manual shall provide information for the test, repair, and overhaul of each repairable component of the assembly down to the lowest level of replacement component. No component shall be considered as a throw-away item or deemed un-repairable except where agreed to by SEPTA.

The manual shall include:

1. Description of how each assembly/subassembly operates within the car system. Each shall include:

2. Block diagrams;

3. Signal flow diagrams;

4. Simplified schematics.

5. Functional wiring and piping diagrams;

6. Completely detailed overhaul procedures:

7. Test and evaluation procedures equivalent to that performed by the original manufacturer, including the requirements for specialized test equipment with sufficient information for SEPTA to procure or fabricate such test equipment.

8. Rewinding procedures in full detail for all rotating and wire-wound apparatus, except as otherwise agreed to by SEPTA.

9. Complete instructions for use, drawings and parts information for special tools so that they may be procured or fabricated by SEPTA.

10. The weights of all components and assemblies that weigh more than 50 pounds. In addition, the weights of major component assemblies shall be supplied (e.g., truck, air conditioning module, air compressor).

11. Maintenance and repair of all diagnostic test equipment.

The above items shall be organized by subsystem and/or function and shall be suitable for use in training programs. Where sufficient clarity of detail cannot be provided due to format size constraints, large scale originals shall be supplied and reference to these shall be made on the reduced size material. Isometric drawings shall show routings and locations of piping, wiring, cabling, and associated apparatus as accurately as possible with supplementary call-outs and views to establish where the item may be
located. Diagnostic test equipment usage shall be incorporated in the procedures, in addition to providing procedures using generic test equipment. Schematics shall include interface between subsystems and related equipment schematics. The schematics shall (where applicable) show pressure, volume, voltage, current values and wave forms. Completeness and accuracy shall be stressed.

17.2.4.1 Bench Test and Repair Information

As part of the scope of this contract, the Contactor shall be responsible for providing full bench test equipment procedures to repair electronic circuit boards within all system components found within the locomotive.

Detailed instructions written to a level as used by the Supplier in their own repair facility, must be supplied by the Supplier and Contractor sufficient to diagnose, repair and test each board. Circuit board schematics, diagrams, part requirements (referrals to the IPC), software and firmware chipset identification, instructions for use of any special software for diagnosis and special tool lists must be supplied as referred to in Section 15.31.35.

The bench test equipment manuals shall be presented as a separate Part B of the associated system’s HRMM chapter within the Heavy Repair and Maintenance Manual.

17.2.5 Integrated Schematic Manual

The Integrated Schematic Manual shall be an integrated schematic defining the electrical and pneumatics arrangement and interfacing of the various Locomotive subsystems. The manuals shall be in 8.5 X 11 and 11 X 17 format. This manual shall include:

- General information;
- List of symbols;
- Sample of how to interpret the schematic diagram;
- Schematic diagrams (shall show input/output for all printed circuit boards);
- Trainline functions (shall include a drawing showing all jumper cable terminations);
- Point to point locomotive wiring list based on wire/cable numbers;
- Wiring diagram sets of all component internal wiring configurations not found on locomotive’s main schematic diagram;
- Device list of all apparatus including symbols, ratings, etc.;
- Location drawings for all components, devices, terminal strips and junction boxes;
- Information shall be supplied for all diagnostic test equipment.
The manual format shall utilize diagrams and illustrations as required to enhance understanding. All procedures shall be proved out in the field on the first unit of equipment and shall be revised as necessary. All schematics shall be verified for system operation and troubleshooting procedures and revised as necessary.

Regarding point to point wiring lists, they shall be formatted in an MS Office Excel file capable for filtering and sorting. The master file shall be provided to SEPTA as part of the master authoring documents sets as required in Section 17.2.10 par 8.

17.2.6 Software Book

One complete set of all program software documentation for the Locomotive shall be supplied to SEPTA in accordance with Section 15.31.3.5 as a reference document for SEPTA’s exclusive use. This restricted data shall not be included in other publications listed in this Section. Data shall be kept up to date as required for other publications per Section 17.2.9. Documentation software shall be developed using Adobe Frame Maker and provided in electronic PDF file form and published version as required in Section 17.2.10 and will be subject to SEPTA approval.

17.2.7 Illustrated Parts Manual

The Parts Catalog shall enumerate and describe every item used on the Locomotive, along with the diagnostic test equipment and special tools with its related parts. All parts shall be included, including materials down to the subcomponent levels of electronic printed circuit boards potentially used during repairs. Parts that are available on the common market ("brand name" items) and/or are typical supply house catalog items shall be identified with the original manufacturer’s name and part numbers or the catalog supply house catalog number.

Each listing including the accepted generic modified noun name description, the original supplier, its part number and name, the Contractor’s part number, all commercial equivalents and provision for entry of SEPTA’s part number within the IPC’s format. An appendix giving the original supplier’s complete address and telephone numbers for their offices responsible for parts ordering shall be included. Email addresses for general inquiry or ordering parts shall also be included. Each component that can be disassembled shall be broken down in illustrations to its indexed parts.

Commercial items that have been reworked by the Contractor must be delineated on an "altered" or "modified" part drawing. This drawing shall list the manufacturer’s part number and describe how the item has been modified. SEPTA shall decide whether to purchase a modified item from the Contractor or process it in-house.

Computer-prepared letter quality text (indented format) with line art work using exploded isometric view drawings of assemblies shall be used to permit identification of each and all parts. Illustrations shall be on a subcomponent level (vs. full component) and accompanied by an associated table. Identical parts, regardless of where used, shall have one part number. Each part or other item shall be identified as being part of the next higher assembly. In the case of hardware such as nuts, bolts, washers, and similar hardware, information relative to material, coating if any, all dimensions and type shall be included. All assemblies shall be listed alphabetically by name with reference to corresponding figure number.
If the same drawing is used in both the Illustrated Parts Manual and either the Running Maintenance or Maintenance and Repair Manual, the reference index in both manuals must identify the same parts.

The Contractor shall also supply three complete sets of the Illustrated Parts Manual text database, along with approved data management software for its use licensed to SEPTA, in compliance with Section 17.2.11.

17.2.8 Structural Repair Procedures
The Contractor shall provide lower level drawings in sufficient detail to enable fabrication or reconstruction of cosmetic and structural members and materials of the carbody and trucks, along with all relevant wiring, piping, schematics hardware appointments and any other relevant information for purposes of wreck repair, including but not limited to:

- Car body information;
- Materials;
- Damage evaluation, trim-back, parts salvage;
- Structural repair;
- Shop practices;
- All weld procedure specifications, etc.
- A procedure and list of all disconnections to sensitive electronic equipment required to perform welding repairs on the locomotive
- A full drawing tree of all structural drawings and components.

17.2.9 Changes and Revisions
Following the approved draft issue of each manual, and continuing with the final approved version, the Contractor shall provide revised pages within 90 days of the need for change being established covering any changes, whether required by Field Modification Instructions, Engineering Change Notices, equipment modification, change of design, drawings or procedures, incompleteness due to error, or any other reason. The manuals shall be kept current during the warranty period, interpreted as that of the longest warranted part of vehicle. Manuals shall not be considered complete or final until all revisions required due to changes or modifications have been included by the conclusion of the warranty. Manuals shall be written for a reading comprehensive level of 9th grade. Writing shall be in a clear American vernacular, and have a “single voice” quality from section to section and chapter to chapter.
17.2.10 **Manual Delivery Schedule**

1. 360 days after Notice to Proceed, the Contractor shall submit a Manual Development Overview Proposal with schedule.

2. 210 days prior to scheduled delivery of the Pilot Locomotive, the Contractor shall submit a Final Manual Development Proposal.

3. In-progress reviews shall be initiated on all publications at least 180 days prior to the scheduled delivery of the Pilot Locomotive.

4. 120 days prior to the scheduled delivery of the Pilot Locomotive, the Contractor shall deliver one review draft copy of the Operating Instruction Manual and the QMP Training Guides to SEPTA for review and approval.

5. Ninety days prior to the scheduled delivery of the Pilot Locomotive, 200 advanced published copies (200/500 total) of the final approved draft of the Operating Instruction Manual and 1 approved electronic PDF version of each QMP Training Guide and appendixes shall be delivered to SEPTA.

6. Sixty days prior to the scheduled delivery of the production locomotive, an electronic set the final approved draft of the Running Maintenance Manual shall be delivered to SEPTA. These manuals shall be used for operation and maintenance of the first unit. Any errors discovered shall be corrected in the approved version.


8. Published copies of the final approved manuals with all information complete in the quantities listed below shall be delivered prior to the delivery of the 12th locomotive to allow for any and all changes incurred during the commissioning of the Pilot Locomotive and early revenue service operation while the remaining locomotives are in production. A full set of updated documents in electronic media shall also be provided at the same time. Prior to the conclusion of the warranty, the Contractor shall supply to SEPTA a complete set of authoring electronic media documents, plus camera-ready master sheets, including artwork, for every manual. Documents should be in Adobe Frame Maker and PDF format.

   - 500 copies (minus 200 advanced copies)- Operating Instruction Manual;
   - 10 copies - Running Maintenance Manual;
   - 10 copies Heavy Maintenance and Repair Manual;
• 10 copies - Maintenance and Repair Manual;
• 40 copies - Integrated Schematic Manual sets.
• 20 copies - Illustrated Parts Manual;
• 5 copies - Structural Repair Procedures Manual;
• 2 copies – Software Manual

17.2.11 Computer Disk Submittal
The Contractor shall provide all manuals and schematics in their originating file formats and PDF versions to SEPTA on electronic media.

17.3 TRAINING

17.3.1 General
The Contractor shall provide an SEPTA-approved User Training Program. This program shall provide adequate coverage to insure safe and satisfactory operation, servicing, troubleshooting, maintenance and overhaul of the Locomotive and all other furnished equipment, such as diagnostic and shop testing equipment.

The Contractor may assume that SEPTA’s maintenance personnel have the basic skills pertinent to their crafts, and a high school education. When creating lesson plans and content, the Contractor shall also assume that such students will be new to the locomotive equipment and its associated systems. Instructional content shall be sufficient to include the context of the subject matter along with theory of operation, troubleshooting, corrective actions for repairs and preventative maintenance instructions. The manuals listed in Section 17.2 shall be used as the major element of the Training Program.

SEPTA, and training subcontractors to SEPTA, shall have access to all facets of Locomotive manufacture and component construction for the purpose of developing and or reviewing training programs. This shall include, but is not limited to, the taking of photographs and video taping. Such access shall be granted upon advance notification (5 days) with the sole purposes of gathering information for training, repair and maintainability of said equipment.

SEPTA shall have access to the Locomotives during performance testing for the purpose of getting hands-on experience with their operating characteristics.

17.3.2 Scope
The Training Program shall employ a combination of formal classroom instruction and "hands-on" training using either actual Locomotive equipment or partial subsystems or components to allow the introduction of faults, fault diagnosis procedures and repair techniques.
The Training Program shall be designed to be classroom oriented using the instructional guides, training aids and simulators as the primary training platform and be coordinated with “hands on training” on the locomotive based on availability during the daily schedule.

The Program shall be based on the use of the manuals as the central source of information to SEPTA personnel using Instructor and Student Guides for the coursesware. No other printed material may be used, except as approved by SEPTA. The classroom instruction, however, shall be presented in an interesting manner, with extensive use of audio-visual training aids such as PowerPoint slides, multimedia presentations, Computer Based Training, oversize diagrams from the manuals and models. Upon completion of the training the student shall not only have a basic understanding of the subject matter, but also be well versed in how to obtain any needed information from the manuals.

The Training Program shall be conducted in English. Instructors shall have a good command of the technical English language used in the North American railroad industry.

During each training course, periodic written quizzes shall be given, concluding with a comprehensive written final examination. Those not showing an understanding of the material, as determined by test scores, shall repeat the subject or unit area found deficient. If an excessive number of personnel (as determined by SEPTA) fail a particular training unit, the Contractor shall investigate the areas in which personnel or the program have shown weaknesses, and revise the training unit to provide more effective training in these areas. Upon the conclusion of each training unit, the Contractor shall have all participants fill out a questionnaire concerning the Program’s strong and weak points, and suggestions for improvement. These suggestions shall be incorporated, as appropriate, into the Training Program.

The instructors used by the Contractor shall be familiar with SEPTA’s operation to a degree appropriate for the particular material being presented, completely knowledgeable on the specific topic/equipment being presented, and have full understanding of the interface of the equipment being presented with other Locomotive equipment. They shall be totally prepared to present the course material, including full responsibility to have available all audio-visual aids such as projectors, screens, flip charts, testing equipment and mock-ups necessary to present their course material. SEPTA reserves the right to check the qualifications and/or references of the proposed instructors and also to reject for cause any instructor not believed to be adequately qualified.

The formal classroom instruction shall be conducted in a suitable classroom furnished by SEPTA on its premises, as required by SEPTA. Informal field instructions may also be conducted on SEPTA's property at its discretion.

If deemed necessary, SEPTA may require the Contractor to provide tours and/or special instructions in the shop facilities of the Contractor and/or its suppliers and manufacturers for a limited number of SEPTA supervisory and technical personnel to familiarize them with the Locomotive assembly methods.

### 17.3.3 Format

The Contractor shall supply both a Student Guide and an Instructor Guide. Each guide shall be organized in such a manner to cover the following subjects:
Theory of operation;

Troubleshooting, including instructions for the use of diagnostic test equipment;

Corrective maintenance covering removal, replacement and detailed adjustment instructions as applicable;

Post-repair system and/or component testing;

Preventative maintenance instructions.

Each guide may be based, but not solely, on Power Point presentations unless all text and instructions are contained within the PowerPoint pages. Any additional details shall contain a cross reference either to the PowerPoint page or vise versa where the PowerPoint refers back to additional text within the guides. An appendix for 11 X 17 fold outs of any poster style visual aids graphics, tables etc. used during the classroom training shall also be included within each guide. All information in the power point program shall be written in a North American vernacular dialect of English.

The instructor’s guide shall mirror the student guide, except within the instructor’s guide, an open guide would show the instructor’s notes on the left hand page and the student’s presentation page on the right hand page. SEPTA shall provide the vendor with a sample of its format. Full copies of the originating file used to create the guides shall be provided along with Adobe Acrobat copies of each guide.

The Contractor shall also provide interactive multimedia instruction (virtual reality simulations) for mechanical and electrical systems determined by SEPTA. These programs would be designed to run on laptop or desktop computers on an operating systems specified by SEPTA.

17.3.4 Train-The-Trainer Approach

The first of every course, the Contractor shall provide a hands-on, Train-the-Trainer course for SEPTA Instructors consisting of running maintenance training and operational training. The purpose of this approach is to evaluate the proposed Training Program and to thoroughly familiarize SEPTA’s training staff with Locomotive assemblies and sub-assembly operation, maintenance, troubleshooting in conjunction with inspection and testing.

Out of the locomotive’s training course curriculum, two train the trainer courses must be completed at the Contractor’s facility prior to the delivery of the Pilot Locomotive. These courses shall be:

1. Operator’s Course
2. Qualified Mechanic Personnel (QMP) Course

All course material shall be complete and ready for actual training upon return to SEPTA.

The remaining Train-the-Trainer courses shall be performed at the SEPTA’s Training Facilities prior to the delivery of the first production locomotive. During the program, the SEPTA Instructors shall review
functional mock-ups and simulators, audio visual aids and methods of instruction proposed in the Contractor’s Training Program. A summary review of maintenance manual status will be confirmed and if found lacking for training, the Contractor will immediately improve prior to delivery of the production locomotive and/or the start of training of SEPTA personnel.

This Train-the-Trainer program shall include classroom instruction, instruction on the shop floor, and use of mock-ups and simulators. The time required for this instruction shall be at least as long as each of the training unit and if appropriate, longer to accommodate questions and discussion between SEPTA training staff and the Contractor training staff. Student and Instructor Guides must be used. Multimedia visual aids shall be included. If production of the visual aids are not complete due to being developed on the first production locomotive, the Train-the-Trainer program may continue with the guides only, however the multimedia visual aids must be delivered prior to the delivery of the first production locomotive and will be subject for review and acceptance via the Train-the-Trainer program.

17.3.5 Local Training

SEPTA shall make available to the Contractor, upon seven days’ advance notice, space at accessible shop locations for educational purposes, and shall arrange for a Locomotive for both operational and the classroom hands-on training portion as needed.

17.3.6 System Simulators

The Contractor shall provide five functional, bench top, microprocessor control system simulators to assist operators and mechanics in becoming familiar with the controls and diagnostic features of the locomotive. Each simulator shall be comprised of:

- The bench top simulator shall be presented in a multimedia tutorial form.

- This simulator shall allow the user to explore and get familiarized with the monitoring information by:
  - Simulation of a set of diagnostic messages available from the typical subsystems found in the locomotive along with the suitable educational multimedia presentation.
  - Guiding the users on how to use the diagnostic information to troubleshoot and develop fault finding procedures.
  - Exploring the potential and the limitation of troubleshooting with the subsystem diagnostics.
  - Training the users on how to initiate an automatic departure test sequence with provision for setting up the simulated departure faults.
  - Getting real subsystem diagnostics information from a nearby trainset or locomotive (line of sight) by a wireless connection.
The bench top simulator shall be used as a tutorial for operators and mechanics on how to set up the train for departure and on how to troubleshoot typical failure modes found on the subsystems.

The bench top simulator shall enhance manuals and training tools by its multimedia capability. It shall allow SEPTA to use it as a qualification tool for mechanics.

The Bench Top simulator shall be connected to a laptop or desktop computer which shall serve as an emulator for the locomotive. The bench top simulator shall possess the portability and protection to be easily shipped between SEPTA locations.

The Contractor shall update all instruction material upon completion of the warranty period to cover any changes or retrofits to Locomotives performed after delivery. Any inconsistency or incorrect information uncovered during the instruction period shall be immediately corrected and formally submitted to SEPTA in the form of replacement drawings, video tapes, lesson plans, mock-ups, schematics and changes in documentation.

17.3.7 Visual Aids

The Contractor shall provide visual aids using multimedia formats including text, audio, still imagery, animation and video to produce its content.

Visual aid productions shall be of high quality, professionally produced by an independent, experienced supplier of such product. The multimedia visual aids shall complement and be consistent with course outlines and student and instructor guides. The scope of the visual aids shall include, but not be limited to general overall instruction on the equipment operation and maintenance consisting of installation and removal, repair, adjustments and troubleshooting procedures for each major component for the locomotive’s electrical, mechanical, pneumatic, and hydraulic systems. Visual aids shall also cover the periodic required maintenance, removal and installation, repair and overhaul of the locomotive’s components.

The Contractor shall provide three (3) sets of multimedia visual aids of professional quality, suitable for instruction, in DVD format. These DVDs shall be provided in library format with an index cross-reference between performance symptoms, component generic name, manufacturer, etc. Videos shall be produced with use of non-studio, railroad shop-type personnel for personal identification with the subject by SEPTA personnel.

The multimedia files produced shall contain all necessary information pertaining to the procedures and have the technical data necessary to perform a specific function such as repair, maintain, or operate all locomotive equipment. Additional written handouts shall also be furnished by the Contractor to cover and support the Computer Based training.

At least six (6) months prior to delivery of the first Locomotive, the Contractor shall identify and submit a list of all items or functions that shall require visual aids to be approved by the SEPTA Program Manager. Production of the visual training aids shall be coordinated by the Contractor with content review by SEPTA representatives from the Operating, Maintenance, and Training departments prior to final submittal of one master set.
All multimedia file scripts and shot lists shall be submitted to SEPTA for evaluation by Engineering, Maintenance and Training departments to assess the training content ensure they meet the training needs prior to development.

Multimedia files shall maintain a quality standard which includes, but is not limited to, the following:

- The picture depicts normal working light or better;
- No jerking motions; i.e. tripods are to be used whenever possible
- Picture is supported by appropriate text, overlays, arrows and graphics;
- Clean breaks and wipes between scenes;
- No unsafe acts or scenes;
- SEPTA Safety Rules are adhered to in all visual aids;
- Audio is professionally narrated;
- Only appropriate background noise; and
- Audio matches picture at all times.
- Digital DVD resolution of 500 lines
- Professionally constructed front ends on all DVD menus.

Format of the multimedia files shall include a “standard series” title at the beginning with the date produced, topic title (introduced by audio plus text) which includes the objective of the DVD, and a standard length of 10 to 15 minutes, and a closure which includes appropriate safety, quizzes and quality messages. Where topics shall need more than 10 to 15 minutes of time for completion, they shall reside on the same DVD but shall be broken down into chapters.

One (1) complete set of DVDs shall be delivered to SEPTA, for review, at least one month prior to delivery of the first production locomotive.

In the event that changes or modifications are performed after delivery of locomotives, the contractor shall make reasonable changes to all visual aid presentations that would render them accurate.

All multimedia productions shall be the property of SEPTA at which time SEPTA shall assume all copyright privileges.

17.3.8 Program Overview Submittal

The Contractor shall submit to SEPTA for approval 360 days after Notice-to-Proceed an overview of the Training Program. Thirty days after SEPTA’s approval of the course overview, the Contractor shall submit
draft copies of all Instructor and Student Guides to SEPTA for approval. After SEPTA's approval of the guide’s format, the Contractor shall submit the full Training Program for approval. Pre-Pilot Locomotive delivery training consisting of Operator and QMP Train-the-Trainer programs shall be required a minimum of 90 days prior to the scheduled shipment of the Pilot Locomotive from the Contractor’s facility. All remaining courses will be due at least 180 days prior to delivery of the first production locomotive.

Program design, format, and delivery shall be in accordance with SEPTA Training Department instructional standards. The scope of each course shall be delineated in SEPTA’s standard course master sheet (sample to be provided). The outline shall include as a minimum the following:

Clear instructional objectives;

- Delivery method;
- Evaluation methods;
- Student aids;
- Instructional aids, including multimedia visual aids;
- Training schedules;
- Train-the-Trainer programs;
- Hours of classroom and hands-on training;
- Qualifications of the instructors;
- A list of training aids to be used.

17.3.9 Organization

The Training Program shall consist of the following courses, developed from the technical manual sets developed for the maintenance, troubleshooting, repair and test of the locomotive. The following courses shall be developed covering all aspects of the locomotive and its associated systems in a comprehensive manner per the subjects listed below:

- Initial Operator Training Course Operations and Transportation Management;
- Operator Training (Locomotive);
- Locomotive Equipment Introduction - Management and Supervision;
- Locomotive Equipment Introduction - Maintenance Personnel;
- Manual Familiarity;
• Inspection and Servicing;

• Theory of Operation, Troubleshooting and Repair;

• Computer and Power Electronics Theory;

• Equipment Overhaul.

• Specialized Qualified Maintenance Personnel (QMP) Training

### 17.3.10 Operators Training

SEPTA Operations and Transportation Managers shall attend the initial Operator Training course presented at SEPTA’s training facility by the Contractor. The initial Operator Training course shall be at least 24 hours in length. This course shall be in addition to the scheduled Operator Training courses.

Manual Familiarity shall be a complete overview and explanation of the various manuals and their use. This shall be included in the introduction courses.

Engineer Training shall provide information needed for the operation of the Locomotives, including definitions giving nomenclature, function, location and operation of all indicators, controls, trainline functions, components and subsystems utilized in the operation of the equipment. This shall include preparing the unit for operation and securing the unit from operation. There shall be special emphasis placed upon on-the-road troubleshooting, emergency procedures, the use of all bypass functions and the possible hazards associated with their use, and the operation of the Locomotive under unusual conditions, such as adverse weather, degraded power supply, or other abnormal factors. This course shall include at least 4 hours in the cab of an operating locomotive.

### 17.3.11 Maintenance Training

The following subjects shall be included in the Maintenance portions of the locomotive training.

#### 17.3.11.1 Locomotive Equipment Introduction, Management

Management and Supervision shall be a course of at least 12 hours in length provided for SEPTA management and supervision personnel and shall be an introduction to the Locomotive equipment and its features, operation, capabilities and maintenance. This course shall be conducted a minimum of three times at a site to be chosen by SEPTA.

#### 17.3.11.2 Locomotive Equipment Introduction, Maintenance Personnel

Maintenance Personnel shall be a course of at least 24 hours in length provided for SEPTA mechanical and electrical equipment maintenance personnel and shall be an introduction to the Locomotive equipment and its features, operation, capabilities, maintenance and troubleshooting. This course shall be conducted a minimum of three times at the Contractor's training facility.
17.3.11.3 Manual Familiarity

Manual Familiarity shall be a complete overview and explanation of the various manuals and their use. This shall be included in the equipment introduction courses.

17.3.11.4 Inspection and Servicing

Inspection and Servicing shall be presented to all shop maintenance personnel. It shall demonstrate all preventative maintenance functions needed on the Locomotive for up to a 5 year period. This shall include all inspection, servicing and lubrication tasks necessary in the running maintenance of the unit. Coverage shall also include demonstrations of lifting and jacking the Locomotive under normal and emergency (i.e., derailment) conditions. Methods of testing the unit to verify proper repair shall be covered. This course shall be at least 40 hours in length.

17.3.11.5 Theory of Operation, Troubleshooting and Repair

Theory of Operation, Troubleshooting and Repair shall be presented to the appropriate qualified shop maintenance personnel. This course shall be divided into subsets for equipment subsystems. Each subset shall include a detailed system description, including all components, their function and operation; adjustments and testing; disassembly and assembly; and removal and installation of the components on the Locomotive. The subsets shall individually address the Operator controls; auxiliary power inverters, battery, and controls; heating and air conditioning including controls; power collection; propulsion and electric braking, motors, gear units, friction braking, and slip/slide control; air compressor, trucks including suspension; use of on-board diagnostics and fault detection equipment. Special tooling and test equipment necessary to service and maintain each system shall be used, and shall become the property of SEPTA upon the conclusion of the Training Program. Time for each subset shall vary in length.

17.3.11.6 Equipment Overhaul

Equipment Overhaul shall be presented on a subset basis to SEPTA's shop personnel responsible for the respective subject area. Each subset shall include a detailed component description, complete disassembly, inspection, wear limit tests and complete overhaul or remanufacturing instructions including motor rewinding, assembly, balancing, seasoning, lubrication, tests, and adjustments. The subsets shall individually address the couplers and draft gear; auxiliary power subsystem including inverters, wiring, battery and controls; heating and air conditioning including controls and auxiliary heaters; power collection; propulsion; electric braking including controls, motors and gear units; friction braking and subsystem; and the trucks including suspension and tilt system (if provided).

A special subset shall address car body structural repairs, including metal shaping, welding, finishing and other required functions. Any special tooling and test equipment necessary to overhaul the equipment shall be used and shall become the property of SEPTA upon the conclusion of the Training Program. Each subset shall be at least 16 hours in length.
17.3.11.7 Qualified Maintenance Personnel Course

QMP – A Qualified Maintenance Personnel (QMP) qualification course shall be developed to establish training to certify and qualify maintenance personnel as required by 49 CFR 238.109 to actively perform inspection, testing to certify equipment for service per 238.301 through 238.319 of the Code of Federal Regulations.

The following inspections and activities shall be developed by the Contractor, have been submitted and have undergone SEPTA approval prior to the course being developed. Each inspection and/or test shall consist of two separate parts consisting of a standalone procedure and separate data sign off sheet. The courses shall consist of at a minimum:

- Calendar Day Exterior Mechanical Inspection
- Calendar Day Interior Mechanical Inspection
- 92 Day Inspection
- 3 Year Air Periodic Brake Equipment Maintenance
- Single Car Test
- Class 1 Brake Test
- Class 1A Brake Test
- Class 2 Brake Test
- Running Brake Test.

17.3.12 Bench Test Equipment Training

Training for each system designated to have bench test equipment associated to it, shall be included within the training program. The courseware shall be based on the same level of detail as all other courses. The Software Book found in 17 shall be available and referenced in BTE training material. Training shall be scheduled based on the fully acceptable commissioning of the bench test equipment. Train-the-Trainer courses will not be required.

17.3.13 Courses, Frequency and Class Sizes

<table>
<thead>
<tr>
<th>Course</th>
<th>Location</th>
<th>Frequency</th>
<th>Class Size</th>
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<tr>
<td>Operator Training (T-t-T)</td>
<td>Contractor’s Facility</td>
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<td>4</td>
</tr>
<tr>
<td>QMP (T-t-T)</td>
<td>Contractor’s Facility</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Course Description</td>
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<td>--------------------------------------------------------</td>
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<tr>
<td>Initial Operator Training Course (Ops &amp; Trans Mgt)</td>
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<tr>
<td>Locomotive Equipment Introduction (Mgt. Sup)</td>
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<td>3 (includes T-t-T)</td>
<td>15</td>
</tr>
<tr>
<td>Locomotive Equipment Introduction (Maint.)</td>
<td></td>
<td>5 (includes T-t-T)</td>
<td>15</td>
</tr>
<tr>
<td>Inspection and Servicing</td>
<td></td>
<td>5 (includes T-t-T)</td>
<td>15</td>
</tr>
<tr>
<td>Theory of Operation, Troubleshooting and Repair</td>
<td></td>
<td>5 (includes T-t-T)</td>
<td>15</td>
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<tr>
<td>Computer and Power Electronics Theory</td>
<td></td>
<td>5 (includes T-t-T)</td>
<td>15</td>
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<tr>
<td>Equipment Overhaul</td>
<td></td>
<td>5 (includes T-t-T)</td>
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</tr>
<tr>
<td>QMP</td>
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</tr>
<tr>
<td>Bench Test Equipment</td>
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<td>2</td>
<td>8</td>
</tr>
</tbody>
</table>

Note: 1. Manual Familiarity will be given with all introduction courses.
Note: 2. “T-t-T” denotes Train-the-Trainer course events.

**17.3.14 Scheduling**

Scheduling of all courses shall be developed concurrently with the development of the maintenance manuals.

1. 360 days after Notice-to-Proceed, the Contractor shall submit a Training Program Overview Proposal with schedule.
2. 450 days after Notice to Proceed, the Contactor shall submit Instructor and Student Guide samples in addition to a major list of all subjects, items and functions identified for multimedia visual aids.
3. 210 days prior to scheduled delivery of the *Pilot Locomotive*, the Contractor shall submit the full Training Program proposal.
4. 180 days prior to scheduled delivery of the *Pilot Locomotive*, the Contractor shall submit the final Operator Training Program and Qualified Maintenance Personnel (QMP) Training courseware.
5. 210 days prior to the scheduled delivery of the first *production locomotive*, In-progress reviews shall be initiated on all remaining training courseware.
6. 90 days prior to the scheduled delivery of the Pilot Locomotive, the Contractor shall submit approved Operator’s Training and QMP Training courseware.

7. 30 day prior to the delivery of the Pilot Locomotive, the Contractor shall present Train-the-Trainer Operator Training and Qualified Maintenance Personnel Training courses at the Contractor’s facility.

8. 90 days prior to the scheduled delivery of the first production locomotive, the Contractor shall present the initial Operator Training course to SEPTA’s Regional Rail Transportation and Maintenance Department supervision its training facility. This course shall be in addition to the scheduled Operator training.

9. 30 days prior to the scheduled delivery of the first production locomotive, the Train-the-Trainer Program shall commence with the first class being conducted at SEPTA’s designated training facility.

10. 21 days prior to the scheduled delivery of the first production locomotive, the Locomotive Equipment Introduction - Management and Supervision course shall be presented at the Contractor's training facility.

11. Upon completion of Locomotive Equipment Introduction - Management and Supervision course, the Locomotive Equipment Introduction - Maintenance Personnel course shall be presented at the designated SEPTA training facility.

17.3.15 Continuing Training

SEPTA’s Training Department shall have the right to record whichever portions of the Training Program it desires for future SEPTA training use.

A complete set of all materials used by the Contractor during the Training Program, including lesson plans, training aids, manuals, mock-ups, special tools, displays and all other components used shall be presented to SEPTA within 30 days of conclusion of the complete Training Program, which shall be properly revised and updated by the Contractor to reflect all equipment modifications until the end of the warranty period.

In addition to the above, the lesson plans, manuals, and training aids shall be provided to SEPTA on electronic media in accordance with Section 17.2.11.

END OF SECTION

2. THE STATIC OUTLINE AND DYNAMIC OUTLINE IS REFERENCED TO THE PLANE OF THE TOP OF RAILS, FOR TRACK WITH AND WITHOUT SUPERELEVATION. FOR A VEHICLE HAVING A MAXIMUM LENGTH OF 86'-0", AND A TRUCK CENTER DISTANCE OF 96'-0".

3. THE VEHICLE MUST REMAIN WITHIN THE DYNAMIC OUTLINE UNDER ALL CONDITIONS, INCLUDING LATERAL AND VERTICAL MOVEMENT OF THE VEHICLE ON ITS SUSPENSION, ROLL INDUCED BY UP TO 6" SUPERELEVATION (WITH THE VEHICLE STOPPED OR IN MOTION), ROLL INDUCED BY THE DESIGN CANT DEFICIENCY, RANGE OF MOTION OF THE TILT SYSTEM (IF SO EQUIPPED), NORMAL WEAR, VARIATIONS OF LOAD, FAILURE OF ANY SINGLE SUSPENSION COMPONENT, AND ANY COMBINATION OF THESE CONDITIONS.

4. THE HORIZONTAL DISTANCE FROM CENTER LINE OF TRACK, FOR VERTICAL DISTANCES BETWEEN 2.75" AND 1'-0" ABOVE TOP OF RAIL, MUST ALLOW FOR THE INSIDE AND OUTSIDE OVERHANG OF THE VEHICLE ON A 12'-30" CURVE, AS SHOWN ON SHEET 3 AND THE SHAPED AREAS OF THE STATIC OUTLINE AND THE DYNAMIC OUTLINE. ALL VEHICLE STRUCTURE, EQUIPMENT, AND APPLIANCES, MUST REMAIN WITHIN THIS OUTLINE UNDER ALL CONDITIONS.